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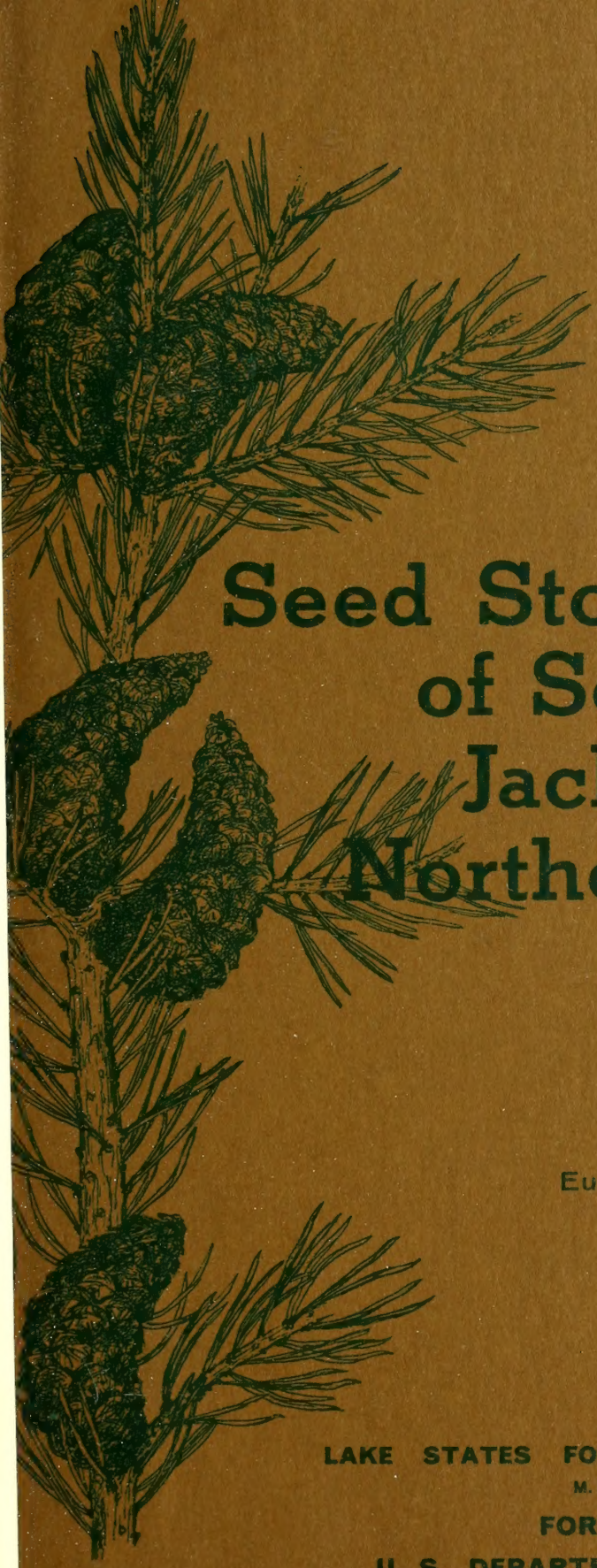

Seed Stored in Cones of Some Jack Pine Stands, Northern Minnesota

Eugene I. Roe

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CONTENTS

Page

REVIEW OF GENERAL CONE AND SEED CHARACTERISTICS 1
- Description and Time of Ripening 1
- Cone Opening and Seed Dispersal 1
- Cone Production 2
- Germination and Retention of Viability 3
- Seed Yield 3

PRESENT STUDY 4

CONE AND SEED PRODUCTION 5
- In Plantations 5
- In 40-Year-Old Timber 5
- In 70- to 80-Year-Old Stands 7
- Of Overmature Trees 9

DORMANCY IN JACK PINE SEED 12

SUMMARY AND CONCLUSIONS 12

LITERATURE CITED 13

PLEASE NOTE

This is the first of a new series of reports to be issued by the Lake States Forest Experiment Station. These reports will be designated "U. S. Forest Service Research Paper LS-—." They replace the Station Paper series, the last one of which was Station Paper 106.

Seed Stored in Cones of Some Jack Pine Stands, Northern Minnesota

by Eugene I. Roe[1]

Over much of the range of jack pine (*Pinus banksiana* Lamb.), its cones persist unopened on the trees for many years. Much of the seed thus accumulating on the trees remains viable and is available to regenerate the stands in the event of their destruction by fire. Since large areas of jack pine in Minnesota are being cut, a knowledge of the amount and quality of seed so stored is important for both natural regeneration and seed collection purposes. Considerable amounts of jack pine planting stock are produced, and there is a growing trend toward direct seeding. Sizable quantities of jack pine seed are needed for both operations.

This paper summarizes information collected on the amount and quality of seed retained in the cones of jack pine stands and trees, ranging from young plantations through mature stands to old veteran trees that are relicts in spruce-fir stands. These data are all from the northern and northeastern parts of the state where the cones are typically serotinous; no samples were obtained from central Minnesota where many of the cones open readily on the trees soon after ripening.

REVIEW OF GENERAL CONE AND SEED CHARACTERISTICS

Description and Time of Ripening

Jack pine cones occur usually in pairs toward the apex of the current season's growth. They ripen in September of the second year after flowering. Newly ripened cones are olive brown and 1 to 1½ inches long; their shape varies considerably from tree to tree. The cones may persist on the trees for 25 years or longer (Ellis 1911),[2] and they eventually become gray. This color appears on the side exposed to the weather about 2 years after ripening. Five-year-old cones are light to dark gray (Beaufait 1960a); old cones are dark gray and are often covered with lichens (Schantz-Hansen 1941).

In a given stand, some trees will have straight cones, others slightly curved cones, and still others strongly recurved cones (Schoenike et al. 1959). Shape is apparently associated with seed yield: In one study, straight cones averaged 46 seeds per cone, slightly curved ones 41 seeds, but strongly recurved cones only 21 seeds (Schantz-Hansen 1941).

In another study, cones with an average of 73 scales bore 50 seeds, of which 40 were filled; these were borne only by the upper 65 to 75 percent of the cone scales (Sterling 1903). This is confirmed by Aase (1915), who found the lower one-third or more of the cones to be infertile. Large cones are said to bear more seeds than small ones (Ellis 1911).

The moisture content of mature cones varies from 12 to 15 percent of oven-dry weight; that of the oldest cones runs about 11 percent (Beaufait 1960a, Schantz-Hansen 1941).

Cone Opening and Seed Dispersal

The dispersal of jack pine seed after it ripens depends on the opening characteristics of the cone. In the southern portions of its range, jack pine bears cones that open readily after ripening. Over most of the range, however, the cones are serotinous, sometimes remaining closed on the tree for as long as 25 years or more (Schantz-Hansen 1941).

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[1] *Research forester at the Lake States Forest Experiment Station. The Station is maintained by the Forest Service, U.S. Department of Agriculture, at St. Paul 1, Minn., in cooperation with the University of Minnesota.*

[2] *Names and dates in parentheses refer to Literature Cited, p. 13.*

In Minnesota, there is evidence that the cone type gradually changes from predominantly serotinous in the northeast[3] to nonserotinous in the central and southern parts of the state (Rudolph et al. 1957). Such a gradation is also suggested for the jack pine range in Michigan, Wisconsin, and the Northeast by observations made by the Station (Rudolf 1958) and by cone counts made of a jack pine seed source study at Cloquet (Schoenike et al. 1959). The dominance of nonserotinous cones in the southern part of the range is reflected in the abundant reproduction in and adjacent to jack pine stands. Where the cones are primarily serotinous, such reproduction is rare.

Although it was believed earlier (Schantz-Hansen 1941) that serotinous and nonserotinous cones were seldom found on the same tree, recent evidence indicates that trees bearing both types of cones occur rather frequently (Schoenike et al. 1959).

Seed dispersal from nonserotinous cones begins in September and may continue intermittently over several years (Rudolf 1958). Both types of cones open readily after a fire in jack pine stands; seed dispersal occurs usually within the next few days (Eyre and LeBarron 1944) but sometimes may be prolonged for several months (Beaufait 1960b). In some instances, serotinous cones have opened and shed their seed in midwinter after periods of extremely low temperatures (Eyre and LeBarron 1944).[4] The reason for this unusual circumstance is not known, but it does not seem to be due to excessive drying of the cones (Beaufait 1960a). Occasionally, cones that have released their seeds will close again during moist weather and, unless closely inspected, will appear to be unopened.

The scales of serotinous cones are sealed, at least in part, by a material that is soluble in both petroleum ether and a 1:2 mixture of alcohol and benzene (Cameron 1953).[5] It may thus be resinous or composed of waxes, fats, or wood gums. Although this substance has not been analyzed, it softens at about 116° F. and melts at 122° F. (Cameron 1953). Once it has been removed with a solvent, the cones will open readily at air temperature, the time required depending on their moisture content.[5] Whether nonserotinous cones have a sealing bond with a lower melting point has not been demonstrated.

The temperature at which serotinous cones will open on the trees in the absence of fire is not known. Presumably it is somewhere in the neighborhood of 122° F. This is, of course, well above the maximum air temperatures commonly experienced within the range of jack pine in Minnesota.

No definite information is available on the temperatures to which the cones are subjected when fire kills a stand. Judging from studies of slash fires in Michigan, these may vary from 600° F. at 17 feet above ground to about 400° F. at 25 feet and 200° at 50 feet (Beaufait 1960b, 1961). Cones will open in a muffle furnace in 80 seconds at 200° F. and in 10 seconds at 800° F. Ignition occurs only when the cones are exposed for 3 to 5 minutes at 700° F; at 900° F. they will ignite in 60 seconds. The seeds show appreciable injury only when the cones burn; then loss in viability is complete. Since the heat of surface fires and crown fires is not known to ignite the cones of standing trees and since very high temperatures in the crowns seem unlikely to last even as long as 3 minutes, it is understandable why fires in jack pine stands do not harm the seed (Beaufait 1960a).

Cone Production

Cone-bearing ordinarily does not begin until jack pine is 5 to 10 years old when open grown and 10 to 25 years when in closed stands (Ellis 1911, Sterrett 1920). Viable seed has been produced by trees as young as 5 years and mature cones (seed quality not reported) by 4-year-old trees (Chisman and Bramble 1951, Wackerman et al. 1929). Production is at its best between 40 and 90 years (Ellis 1911, Sterrett 1920) and declines thereafter. Good crops of cones are said to occur every 3 to 4 years (U.S. Forest Service 1948); others feel that there is no definite seed crop pattern (Ellis 1911).

Production per tree varies. Ellis (1911) reports that a mature jack pine 15 inches in diameter and 90 feet in height will produce annually 300 to

[3] *Even here there are some nonserotinous cones produced (Schoenike et al. 1959). Seedfall in a partially cut mature stand on the Superior National Forest averaged 10,000 seeds per acre per year for a 5-year period (Eyre and LeBarron 1944).*

[4] *Unpublished data on file at the Lake States Forest Experiment Station.*

[5] *Neumann, F. Philip. Scale movements of jack pine cones. Unpub. Master's thesis, Univ. Minn., 24 pp., illus. (Typescript.)*

500 cones bearing 10 to 30 seeds per cone. Sterrett (1920) cites even higher figures: 1,000 to 1,200 cones annually with an average of 30 seeds per cone or about ¼ pound of seed for well-developed, vigorous trees.

Once the flowers have been fertilized, cone production may be reduced by various agents. One of these is the oak-pine rust (*Cronartium quercuum*), which causes the production of smaller cones with a higher proportion of empty seeds (Weir 1915). Another is cone-destroying insects. As yet little attention has been paid to such insects (the only reference available is Sterling (1903) who found unidentified insects destroyed the seed in about 7 percent of the cones); but judging from their importance in other pines, they likely cause appreciable losses of jack pine seed. After the cones are mature, many are cut off and opened for their seeds by red squirrels (*Tamiasciurus hudsonicus*) (Cheyney 1929, U.S. Forest Service 1941). In cutting off the paired cones, these animals often strip off considerable bark. This injury usually kills that part of the branchlet above the cones and thus indirectly reduces cone yields. Red squirrels will also cut off many branches bearing 1-year-old conelets (Cheyney 1929).

Germination and Retention of Viability

Jack pine seed ordinarily is not dormant and will germinate readily and completely in petri dishes (temperature 75° F.) in 4 to 11 days. Germination of seed covered with sand in flats requires several more days. Under natural conditions, seed germinates rapidly when moisture is favorable and the 10-day mean maximum air temperature exceeds 64° F. (U.S. Forest Service 1939).

The seed is relatively small; when dewinged and cleaned commercially, it averages 130,600 per pound (U.S. Forest Service 1948). Fresh hand-cleaned seed shows high germination, 90 percent or more.[6] Viability of seed stored in serotinous cones decreases with age, but the loss in germination capacity does not appear to be of much significance until the cones are 3 to 6 years old (Eyre and LeBarron 1944, Schantz-Hansen 1941). Seed from cones that are covered with lichens (and presumably 20 or more years old) may average as high as 50 percent in germination (Schantz-Hansen 1941). One report indicates 82 percent viability for seed from 16-year-old cones.[7] A somewhat better measure of the retention of viability would, of course, be the real germination which, based on filled seeds alone, compensates for fluctuations in the number of empty seeds. Nevertheless, these values do show that a sizable proportion of the seed in serotinous cones remains viable for a long period.

Seed Yield

Only a few data have been collected on the amount of seed available in the cones of jack pine stands. The yield from 1 acre of mature trees 60 to 65 years old on the Chippewa National Forest (all cones collected) agrees quite closely with that from a similar stand on the Superior National Forest: 38.5 vs. 31.4 bushels of cones and 12.9 vs. 13.5 pounds of seed per acre. Of these yields, over half of the approximately 2,000,000 seeds per acre came from cones over 4 years old (Eyre and LeBarron 1944). Germination ranged from 30 to 62 percent for seeds from the oldest cones to 77 to 84 percent for those from 2-year-old cones (Eyre and LeBarron 1944, Rudolf and Ralston 1953).

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[6] *Commercial lots usually run much lower; this is presumably because of injury to the soft seed during the dewinging process.*

[7] *Shen, H. L. Viability of the seed of jack pine from cones retained in the trees for various periods of time. Unpub. thesis, Univ. Minn. 1936.*

PRESENT STUDY

Since the early 1940's thousands of acres of overmature jack pine have been cut in northern Minnesota. The regeneration of such stands has, therefore, become of great importance. Reports from the Superior National Forest in the late thirties and early forties indicated that cone production had averaged only about 5 percent of normal.[8] Such reports suggest that the data reported by Eyre and LeBarron (1944) on the stored seed in mature jack pine in the mid-thirties may no longer be valid. Accordingly, cone production and yield data were obtained from two 70- to 80-year-old stands in the Superior. Later, smaller amounts of data were also obtained both from well-stocked younger stands (plantations on the Superior and 40-year-old timber on the Chippewa) and old, overmature trees (130, 186, and 196 years old) on the Superior.

Essentially, the procedure consisted of collecting representative samples of closed cones, extracting and cleaning their seed, and making germination tests to determine the number of viable seeds per cone. The cone quantity and quality data were then applied to stand tables to give the number of viable seeds per acre. However, some of the details varied from stand to stand.

In each of the four plantations sampled,[9] all of the cones were picked from seven trees, which were equally spaced diagonally across the plantation. For each plantation the average number of cones per tree multiplied by number of trees per acre gave cone production per acre. Likewise, seed production per acre was obtained by applying the seeds-per-cone averages (both total and viable) to the cone production per acre.

In the 40-year-old natural stand a complete cone count was made on 51 trees, covering the range in diameters present, which were cut in a National Forest thinning operation near Cass Lake. Of these trees, 33 were cut in a stand that had received three earlier thinnings; the remainder were taken from adjacent unthinned timber. All were measured for d.b.h. and total height and were classified as to crown position by the Lake States Tree Classification (Gevorkiantz et al. 1943). The average number of cones per tree was determined for each diameter class,[10] and these figures applied to local stand tables for thinned and unthinned stands to give the total production of cones per acre. The yield of seed, both total and viable, was then determined for average cones and these values used to convert cone production into seed per acre.

In the 70- to 80-year-old stands, complete counts were made of the closed cones on 44 trees, sampling the range in diameters present, which had been either cut in logging or recently blown down by wind. Data were recorded by cone-age groups and diameter classes to give the average yield for trees of different size. Four cone-age groups[11] were used for the 26 trees located in blowdown timber near Isabella. However, because of the extremely low temperatures when the counts were made, only two age groups (1942 to 1949 cones and older cones) were used for the 18 trees felled on a winter-logging job at Norway Lake about 18 miles northwest of the Isabella stands. In the final analysis, the data from the Isabella stand were also combined into these same two groups because the younger cones (those maturing between 1942 and 1949) showed close agreement not only in seeds per cone but also in their germination. Seed production per acre was obtained in the same manner as for the 40-year-old stand.

The cone samples from the overmature trees were also obtained from windthrown or logged trees, but because of the infrequency of these older age classes few trees could be included. Furthermore, only the younger cones were collected, since the objective in these cases was to determine to what age jack pine can produce viable seed.

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[8] *LeBarron, R. K. Report on "Reproduction and timber marking studies on Tomahawk-Kraft Paper Company sale area," Dec. 15, 1943. In files of Lake States Forest Experiment Station.*

[9] *Each was of Superior National Forest origin.*

[10] *These values were read from curves of cone production over d.b.h.*

[11] *These were: new cones (1949); cones 1 year old (1948); cones 2 to 7 years old (1942-1947); and old cones 8 to about 20 years old (before 1942). In the last group, cones that were somewhat soft, indicating possible opening and closing, were not included nor were cones with obvious worm holes.*

A brief description is needed on how seed counts and germination tests were made. After collection, a representative sample of the cones (or all cones where the number was limited) was drawn from each lot and counted. This was placed in a screen on a hot steam radiator. After the cones opened, they were shaken vigorously to remove the seeds. When this did not result in complete extraction, the cones were put momentarily in water and returned to the radiator for a second drying. If this procedure did not release all the seeds, another such cycle was used.

The seed was wetted and rubbed gently in a fine screen to loosen the wings. After the seed had dried, the wings and other light debris were removed by winnowing. Although this process got the seed quite clean, it did not, of course, remove many of the empty seeds. Consequently, the lots ran lower in soundness than the usual jack pine seed cleaned commercially in a fanning mill.

From each lot of seed thus obtained, a representative sample was drawn for germination tests. (If the yield was small, the entire yield was used.) Tests were run on moist filter paper in standard petri dishes kept, in the absence of a suitable germinator, at room temperature for 20 to 30 days. This somewhat crude arrangement proved adequate. Seeds remaining ungerminated at the close of the tests were cut to see if they were sound, spoiled, or blind. The following data were then calculated: actual germination (that based on all seeds sown), real germination (based on filled seeds only), viable seeds per cone (germinating plus sound seeds), and total seeds per cone (viable plus spoiled and blind seeds).

● CONE AND SEED PRODUCTION

In Plantations

Since the plantation cones contained many small seeds that were believed to be empty, each of the four seed lots after dewinging was separated into two fractions: (1) That passing through a 5/64-inch round hole grain screen, and (2) that retained by such a screen. As expected, the seed retained by the 5/64 screen was substantially heavier than that which passed through; it averaged 119,500 seeds per pound compared to 153,200 seeds for the smaller seed (table 1). Combining the two sizes gave 134,300 seeds per pound, indicating that the seed generally was of average size (Seed Manual average is 130,600) (U.S. Forest Serv. 1948).

Actual germination, considering that the seed was hand-cleaned, was good; it varied but little from plantation to plantation. And real germination, except for one sublot with 96 percent, was 99 and 100 percent. Since the seed was of remarkably uniform viability (table 1), it was pointless to segregate the two seed-size classes. They were, therefore, combined for the calculation of both seeds per cone and seeds per acre.

Except for the oldest plantation, the total number of seeds per cone and the viable seeds per cone showed little variation. The number of cones produced, however, was considerably more variable. As a result, there was a wide range in both total seed and viable seed production. But even the poorest yielder, the oldest plantation (with its fewer cones per tree and much fewer seeds per cone) had 332,000 viable seeds per acre or more than 2½ pounds of seed. And the best plantation had 5 pounds. These amounts would certainly be adequate for replacing such stands if they were destroyed by fire.

In 40-Year-Old Timber

In the 40-year-old timber, the thinned stand bore more than twice as many cones per acre as the unthinned stand and, while the former yielded fewer seeds per cone, a much higher percentage of them germinated. As a result, seed production in the thinned stand was over three times that of the unthinned timber (table 2 and fig. 1).

Cone production increased with diameter (table 2). Height also was related to production as will be seen in the following tabulation:

Height of trees	*No. of cones per tree*		*Basis, no. of trees*
	Average	*Range*	
37-44	14	0-32	14
45-50	76	0-308	16
51-56	118	8-352	20

TABLE 1. — *Amount and quality of seed in closed cones of well-stocked jack pine plantations Superior National Forest*

Total age (years)[1]	Size of seed	Clean seeds per pound	Germination		Seeds per cone		Basis cones[3]	Trees per acre	Cones per acre	Seeds per acre[4]	
			Actual	Real[2]	Viable	Total				Viable	Total
		Number	*Percent*	*Percent*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
9	Large	118,900	88	99	36.8	41.4	369	650	17,132	630,500	709,300
	Small	154,400	90	100							
10	Large	114,800	89	99	35.5	39.0	142	550	11,157	396,100	435,100
	Small	157,200	94	99							
11	Large	115,600	94	99	34.0	36.2	136	600	11,657	396,300	422,000
	Small	146,300	94	96							
13	Large	131,000	88	99	26.7	29.9	128	680	12,434	332,000	371,800
	Small	153,500	92	99							
ALL	Large	119,500	89	99							
	Small	153,200	92	99							
Weighted average or total		134,300	91	99	34.4	38.2	775	626	13,862	476,900	529,500

[1] Includes 2 years for age of planting stock.

[2] Based on filled seed only.

[3] Total production of 7 trees in each plantation except for the 9-year one; this was a much larger plantation and had 14 trees sampled.

[4] Production per tree times the number of cones per acre.

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FIGURE 1. — 40-year-old jack pine, Chippewa National Forest. This thrice-thinned stand bore over ¾ million viable seeds per acre (5.8 pounds) in its closed cones.

TABLE 2. — *Amount and quality of seed stored in cones of well stocked stands of 40-year-old jack pine, Cass Lake, Minn.*

D.B.H. (inches)	Unthinned stands			Thinned stands		
	No. of cones		No. of trees sampled	No. of cones		No. of trees sampled
	Per tree	Per acre		Per tree	Per acre	
4	0	0	0	25	2,250	5
5	23	1,932	2	42	3,864	4
6	53	4,346	5	55	4,785	7
7	69	4,347	2	77	8,239	7
8	82	2,460	4	118	5,310	7
9	92	184	3	192	3,840	3
10-11	103	103	2	192	576	0
Total		13,372	18		28,864	33
Viable seeds per cone			16.9			26.3
Viable seeds per acre			226,000			759,100
Total seeds per cone			33.0			28.9
Total seeds per acre			441,300			834,200

Crown position appears to affect cone production; the number of cones per tree tends to decrease as crown position becomes progressively less dominant:

	No. of cones per tree	*Basis no. of trees*
Crown class:		
Open grown	128	1
Head dominant	168	7
Strong dominant	64	15
Conditional dominant	81	14
Codominant	48	10
Intermediate	7	3
Suppressed	0	1

In 70- to 80-Year-Old Stands

In the 70- to 80-year-old stands, cone production in the Isabella trees averaged higher than that at Norway Lake. However, since there was no stand-table information available for either area, their data were combined. The average yield per tree (fig. 2) was then applied to the stand table used for medium-stocked jack pine poles by the Superior National Forest to give the cone yield per acre (table 3).

For both young and old cones, the yield per tree increased markedly with diameter, the largest trees being the best producers. The average tree bore about as many old cones as young ones. As in the 40-year-old stands, total yield per tree tended to increase as crown position became more and more favorable. This conclusion, however, is based on only 14 trees.

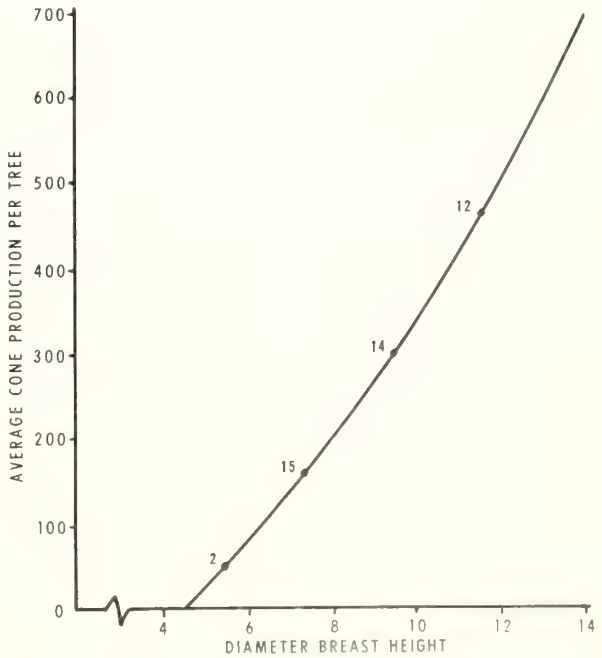

FIGURE 2. — Average yield of cones per tree in relation to diameter; 70- to 80-year-old jack pine, medium stocking, Superior National Forest. The encircled numbers are the numbers of sample trees in each diameter class.

TABLE 3. — *Average and per-acre yields of cones by trees of different diameters, 70- to 80-year-old jack pine of medium stocking, Superior National Forest*

D.B.H. class (Inches)	Yield per tree: No. of —				No. of trees per acre[1]	Yield per acre: No. of —		
	Young cones ripening 1942-1949	Old cones ripening before 1942	All cones	Basis, no. of trees		Young cones ripening 1942-1949	Old cones ripening before 1942	All cones
5-6	25	23	48	2	85.1	2,128	1,957	4,085
7-8	78	91	169	15	63.2	4,930	5,751	10,681
9-10	128	171	299	14	16.3	2,086	2,787	4,873
11-12	264	199	463	12	2.3	607	458	1,065
[2]13-14	355	296	651	1	0.7	249	207	456
Average all diameters	170	165	335					
Total				44	167.6	10,000	11,160	21,160
Average annual production						1,250	[3]797	

[1] From stand table for medium-stocked jack pine pole timber, Superior National Forest.

[2] The total yield of all cones was read from a curve as the one tree sampled bore 2,356 cones, almost 1,100 cones more than was borne by the next best tree. The ratio of young cones to old cones actually shown by this tree was then applied to the figure read from the curve.

[3] Based on an average age of 14 years.

Although Ahlgren (1959) found a total of 5,928 cones on one tree (size and age not given) on the Superior National Forest, the maximum number found on any of the 44 trees in this study was 2,356 (a 13-inch tree); the average yield, however, was only 335 cones. In contrast, the study made on the Superior in the mid-thirties showed 3,442 and 509 cones respectively.[12]

The largest annual crop found on any of the 44 trees was 198 cones, a 13-inch tree showing this production in 1949 and 167 cones in 1948. Although the maximum annual yield per tree in the earlier study was 363 cones (in 1935), the average for the 20 best trees in that same study was only 194.[12] It, therefore, seems that the average annual production of 300 to 1,200 cones per tree reported for mature jack pine by Ellis (1911) and Sterrett (1920) is much too high for this locality.

Cone production per acre averaged only 1,250 per year during 1942-49 and 798 per year prior to 1942 (table 3). This is in marked contrast to the average annual production of 6,059 cones per acre found in the earlier study on the Superior[13] and thus agrees with the observations made by LeBarron.[14] Although a considerable improvement in cone production had occurred since 1942, seed production was still well below that during the mid-thirties (Eyre and LeBarron 1944).

Cones produced before 1942 contained only half of the total seeds per acre yielded by those ripening since that time (table 4). This may have been the result of loss of some seed due either to opening and closing of the cones over the years or poorer cone and seed development. But, in spite of their relatively low number of seeds, these old cones were numerous enough to contribute about 30 percent of the total yield of viable seed.

Germination, considering that the empty seeds (a fourth of all seeds) were not removed by fanning as in commercial seed, was quite high. Although Schantz-Hansen (1941) found that the percentage of empty seeds was higher in the older cones, this was not true of these data. The lower germination shown by seed from the old cones was due mostly to the failure of 15 percent of the filled seeds to germinate; presumably these were already dead when the test began. This explains the much lower real germination shown by the seed from old cones.

[12] *Unpublished data, Lake States Forest Experiment Station.*

[13] *Unpublished data, Lake States Forest Experiment Station.*

[14] *See footnote 8, p. 4.*

TABLE 4. — *Quality and yield of seed stored in cones, 70- to 80-year-old jack pine of medium stocking, Superior National Forest*

Item	Cone origin		Total
	1942-1949	Prior to 1942	
Germination:			
Actual, percent	74	60	....
Real, percent[1]	97	80	....
Proportion of seeds:			
Spoiled, percent	2	15	....
Empty, percent	24	25	....
Basis, no. of cones	192	121	....
Seeds per cone:			
Viable, no.	26.9	10.0	....
Total, no.	36.4	16.8	....
Seeds per acre:			
Viable, no.	269,000	111,600	380,600
Total, no.	364,000	187,500	551,500

[1] Based on filled seed only.

Since the data given by Eyre and LeBarron (1944) on the stored seed supply on the trees of this age class when they were about 15 years younger are given in pounds of total seed, no direct comparison of the two periods can be made. However, translating the total yield of seed at 80 years into pounds by using the Seed Manual average of 130,600 seeds (U.S. Forest Serv. 1948) gives only 4.2 pounds (fig. 3) compared to the 13.5 pounds produced in 1935-36. And of these 4.2 pounds, only one-third came from cones produced before 1942. Further comparisons show that the viable seed supply of these mature stands was lower than that of most of the plantations and the thinned 40-year-old timber but was higher than the yield of the unmanaged 40-year stand.

Of Overmature Trees

The older trees had such limited bases that no attempt was made to determine the stored seed potential of such trees. Furthermore, the rather extensive 130-year age class on the Superior has only a light stocking of about 80 trees per acre; and the two older age classes sampled, 186 and 196 years, have such scattered trees that seed-per-acre figures would be rather meaningless. Of more importance is the knowledge whether such old, overmature jack pine can produce viable seed at their advanced age.

130-Year-Old Windfall. — In September 1949, fifteen gray cones that had been produced sometime during the period 1940 to 1947 were picked at random from the light crop borne by a 16-inch windfall near Forest Center, Minn. This tree, in the 130-year age class, had blown down in the severe windstorm of July 4. No 1948 cones and only two underdeveloped ones of the 1949 crop were found.

The cone sample, which comprised about one-third of the total crop, showed the following germination and seed yields:

Actual germination	82 percent
Real germination	91 percent
Empty seeds	11 percent
Spoiled seeds	7 percent
Viable seeds	22.6 per cone
Total seeds	28.0 per cone

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FIGURE 3. — 70-year-old jack pine, Superior National Forest. Stands such as this may contain over a half million viable seeds (4.2 pounds) per acre in their serotinous cones.

F-501990

FIGURE 4. — Decadent 186-year-old jack pine relict. This 16-inch tree had borne an average of 12 viable seeds per cone in 1949-1951; it was blown down in the late fall of 1951.

Yields of seed were, therefore, appreciably lower than those from cones of comparable age in the 70- to 80-year-old stands.

186-Year-old Relict. — A total of 61 cones maturing in 1949, 1950, and 1951 were picked at random from the top of a windthrown jack pine relict in a cutover balsam fir stand at Heart Lake on the Superior National Forest in late October 1951 (fig. 4). The tree was 16 inches d.b.h. and 186 years old. Since the cones varied considerably in length, they were separated into three size groups and their seeds were extracted and subsequently germinated.

The number of seeds per cone was even lower than the yield from those produced by the 130-year-old tree (table 5). Yield was definitely related to cone size. Although no cone-scale counts were made here, it seems likely, as has been found elsewhere,[15] that the largest cones had the greatest number of scales. This would explain their larger number of seeds. The proportion of empty seeds was also related to cone size, the number increasing as the cones became smaller.

196-Year-old Relicts. — The oldest jack pines known in Minnesota, and perhaps in the Lake States, are a few 196-year-old[16] trees on the Sand Lake Experimental Forest of the Kimberly-Clark Corporation. Judging from the down trees, they were the remnants of a jack pine stand that had been succeeded mostly by balsam fir. Representative 1- and 2-year-old unopened cones were obtained in October 1955 from the tops of two trees, one 16 and the other 20 inches d.b.h., which had been logged in June 1954 in connection with a balsam fir thinning study. Somewhat older cones were picked from a windfall that had been down for 3 or more years; this bore much smaller cones than the logged trees.

Since we know of no published records of the germination of jack pine seed from such old trees, the data are presented in table 6.

The number of seed per pound was determined for the seed from the 20-inch tree. However, since a third of these seeds were blind, this figure, 201,300 seeds per pound, does not give a reliable picture of the relative size of this old seed. The data do indicate that jack pine can still produce cones with an appreciable yield of viable seed at

[15] *Unpublished data, Lake States Forest Experiment Station.*

[16] *Age determined by ring count on a sound 2-foot stump.*

almost 200 years of age. Although no cone counts were made, the 16-inch tree produced cones until 2 years before cutting and the 20-inch tree had a heavy crop of cones of several years' origin. It, therefore, seems likely that both trees bore an appreciable amount of viable seed.

TABLE 5. — *Quality and yield of seed from cones produced in 1949-1951 by a 186-year-old jack pine, Superior National Forest*

Cone length (inches)		Germination		Empty seeds	Spoiled seeds	Seeds per cone		Basis, cones
Class[1]	Average	Actual	Real			Viable	Total	
		Percent	*Percent*	*Percent*	*Percent*	*Number*	*Number*	*Number*
1.31-1.70	1.44	71	97	27	2	19.3	27.0	15
1.10-1.30	1.20	64	99	35	1	11.2	17.5	28
0.91-1.09	1.05	49	98	50	1	6.7	13.8	18
ALL	1.22	63	98	36	1	11.9	18.8	61

[1] The longest cone was 1.70 inches; the shortest, 0.92.

TABLE 6. — *Quality and yield of seed from 1- and 2-year-old cones produced by three 196-year-old jack pines, Superior National Forest*

Tree condition	D.B.H.	Cone data					Germination		Empty seeds
		Origin	Avg. dry weight	Yield of seeds		Basis, cones	Actual	Real	
				Viable	Total				
	Inches	*Year*	*Gms.*	*Number*	*Number*	*Number*	*Percent*	*Percent*	*Percent*
Windfall	14	1949-51[1]	2.4	1.3	6.8	10	19	100	81
Cut but not used, decayed	16	1952[2] -	6.2	13.3	18.9	14	68	96	32
Cut and used	20	1953[3] -	6.1	15.1	25.0	12	66	97	33

[1] Estimated.

[2] No cones produced in 1953.

[3] Would have produced cones in 1954 and likely in 1955 as tree bore many partially developed cones and had also flowered heavily in 1954.

DORMANCY IN JACK PINE SEED

In a recent paper, Ahlgren (1959) suggests that fire may stimulate the germination of jack pine seed through the possible "action of heat in breaking the partial dormancy of seed frequently found in this species." This would seem to deserve detailed study, for in one test made of the seed from jack pine cones that had been partially charred in a slash fire the writer found that none of the seed would germinate even after alternations of favorable temperatures and chilling in a refrigerator. Yet the seed was still firm and apparently sound after about 100 days. This behavior suggests that the exposure of jack pine cones to temperatures high enough to scorch them, rather than favoring germination, may sometimes induce dormancy in this typically nondormant seed.

Such a possibility is also suggested by the results of seedling counts made 13 months after a mid-June crown fire in a 70-year-old stand of jack pine near Tofte, Minn. Although the cones had shed practically all their seeds within a week after the fire and just before a good rain, germination counts showed that 87 percent of the seedlings had originated the second spring. On the other hand, some spring fires hot enough to burn off the needles are followed by an abundance of first-year seedlings. Beaufait (1960a) obtained high germination, apparently without trouble, of seeds from young cones exposed to 900° F. for 30 seconds. However, when exposure was lengthened to 60 seconds at this temperature, the seed was all killed. Since the failure of the seed to germinate for 1 or 2 years after a fire has also been observed in Michigan (Beaufait 1962), further study of the possibility that extreme heat may induce dormancy in jack pine seed seems needed.

SUMMARY AND CONCLUSIONS

The number of closed cones borne by representative jack pine trees in stands of different ages in northern Minnesota was counted, and the number of cones per acre was estimated. Sample lots of cones were then opened by drying, and germination was tested. The average numbers of total seeds and viable seeds per cone were then applied to the cone counts to give total and viable seed per acre. Stored-seed estimates were thus made for four 9- to 13-year-old plantations, two 40-year-old stands, and two 70- to 80-year-old stands. In addition, tests of viability were run on seed from cones borne by 130-, 186-, and 196-year-old trees.

In both the 40-year-old and 70- to 80-year stands, the number of cones produced increased with d.b.h. The limited data available also indicated that within a given stand, cone production increased as crown position increased in dominance.

The amount of viable seed stored in the cones varied from 226,000 per acre in the 40-year unthinned stand to 759,000 for thinned timber of this age. Intermediate were 70- to 80-year jack pine with 381,000 and the plantations with 477,000 per acre. This is a range of 1.7 to 5.8 pounds of germinable seed, an amount which would be much more than ample under favorable conditions to regenerate these stands should they be destroyed by fire.

In the stands tested, the plantations bore appreciably fewer cones than any except the 40-year unmanaged timber. However, their greater yield of seed and its high germination made them second only to the thinned stand in viable seed supply. The greatest number of cones was borne by the 40-year-old thinning; this plus its sizable number of viable seeds per cone resulted in its superior yield.

The 70- to 80-year-old stands showed much lower cone and seed production than similar timber when it was 15 years younger. Total stored seed was less than one-third of the supply found in 1935, while that from the cones ripening before 1942 was about one-tenth as much. The improvement in cone production since 1942 suggests that at least part of the low cone yield of the late 30's was due to adverse climatic conditions, possibly drought.

Cones 8 or more years old in the 70- to 80-year-old stands yielded less than half the seeds per cone, both total and viable, produced by younger

cones. But since there were more older cones on the trees, they contributed almost a third of the viable seed. The lower yield of viable seeds in older cones was due in part to the fewer total seeds they contained and in part to the presence of an appreciable number of dead seeds, for empty seeds were no more numerous here than in younger cones.

Dead seeds were of no consequence in any of the other cone lots tested except in one from a 130-year-old tree in which they amounted to 7 percent.

The study also shows that jack pine produces viable seed to an age of almost 200 years and possibly longer. The number of viable seeds per cone, however, generally decreases with age. To some extent, this is paralleled by a reduction in the total number of seeds per cone and an increase in the proportion of empty seeds. This may be due to a combination of decreased fertility and smaller cone size. Some very old trees appear to produce sizable crops of cones of near-normal size. Others bear only a few small cones, and still others have numerous cones quite variable in size. The yield of seed by at least one overmature tree was directly related to cone size. The smallest cones also bore the highest proportion of empty seeds.

Jack pine seed from cones exposed to temperatures high enough to scorch them sometimes fail to germinate but at the same time appear to be viable. This suggests the possibility that high temperatures may sometimes induce dormancy in this normally nondormant seed.

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Forest Soil Freezing and the Influence of Management Practices, Northern Minnesota

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CONTENTS

	Page
STUDY OBJECTIVES	1
AREA AND TYPES STUDIED	2
METHODS	2
RESULTS	2
Natural Factors	3
Effect of Snow Depth	3
Effect of Soil Texture on Freezing	3
Freezing in Organic Soils	4
Management Factors	5
Forest Versus Open	5
Comparison of Cover Types	5
Effect of Thinning in Dense Conifers	6
Effect of Thinning in Aspen	6
SUMMARY	7
LITERATURE CITED	7

FOR YOUR REFERENCE FILE

Four abstract cards are included at the back of this report for the reader's convenience.

Forest Soil Freezing and the Influence of Management Practices, Northern Minnesota

By
Sidney Weitzman and Roger R. Bay

How the forest affects water behavior is now under study as part of an overall program of watershed research in the Lake States. In this northern climate, soil freezing is an important phase of the hydrologic cycle: The presence and character of frost in the ground determine whether water enters the soil or runs off the surface (Augustine 1941, Coleman 1953).[1]

One frost type, known as concrete frost, limits the infiltration of snowmelt during winter and early spring thaws (Stoeckeler and Weitzman 1960, Trimble *et al.* 1958). Severe spring floods and erosion have been attributed to precipitation on frozen ground (Storey 1955). The floods of 1950 in the Upper Mississippi and Lake Superior basins, which caused damage estimated at 5 million dollars, came during heavy rains on a snowpack covering frozen ground (U.S. Dept. Int. 1953). In northern Minnesota, as much as 50 percent of the total annual runoff normally occurs in a 2-month period in early spring when the ground may still be frozen.

To get some background on frost behavior in the forests of northern Minnesota, the depth and occurrence of concrete frost were observed during two winters, 1957 and 1958. Three locations that cover a range of soil cover conditions were selected to learn something of the distribution of forest frost in the area.

● STUDY OBJECTIVES

Earlier sudies show that concrete frost occurs less frequently, does not last as long, and is not as deep in a forest as in soils on open-land areas (Bay 1960, Bay *et al.* 1952, Hale 1950). However, the influence of the many cover types in the Lake States, the influence of local management practices, and the nature of underlying soils have not been adequately considered.

The major purpose of this study was to observe the incidence and depth of soil freezing at three selected areas that present a range of soil-cover conditions in northern Minnesota. This was an important first step since there have been large-scale changes in land use in that area. On approximately 38 percent of the land in the State, forest cover has been removed and converted to open land (Cunningham *et al.* 1958). Other cover types have been radically altered from pure pine and mixed pine-hardwood to aspen and aspen-brush. Do these changes modify the incidence of concrete frost? If so, what changes in cover are needed to reduce the incidence of concrete frost?

At the same time the role of other factors that affect soil freezing, such as the nature of the underlying soil, was observed. It is well established that in unfrozen conditions the soil is a key factor in water behavior. Does soil, in conjunction with cover, also play an important role in soil freezing? Snow depth was another factor studied, since it influences freezing and can be manipulated by forest practices.

Lastly, the influence of forest practices, such as thinning and reforestation, on soil freezing was observed.

The results, presented here, will help to enlarge our understanding of how forest practices and watershed management are interrelated locally.

Note: Mr. Weitzman is Chief of the Watershed Management Division of the Lake States Forest Experiment Station. Mr. Bay is a Research Forester at the Station's Silviculture and Watershed Management Laboratory at Grand Rapids, Minn.

[1] *Names and dates in parentheses refer to "Literature Cited" at the end of this report.*

AREA AND TYPES STUDIED

Soil freezing was observed under different forest and soil conditions characteristic of northern Minnesota. The 18 plots studied, all located either on or adjacent to experimental forests, are listed below:

Experimental forest	*Soil texture*	*Cover type and treatment*
Pike Bay	Very fine sandy loam to silt loam over clay loam till (Nebish-Rockwood series)	Aspen—80 sq. ft. basal area per acre
		Aspen—65 sq. ft. basal area per acre
		White pine-hardwood
		Balsam fir
		Red pine plantation
		Aspen-brush
		Open
	Deep loamy fine sand (Menahga series)	Jack pine
		Aspen
Cutfoot Sioux	Loamy fine sand to medium sand	Aspen
		Red pine—60 sq. ft. basal area per acre
		Red pine—140 sq. ft. basal area per acre
		Open
Big Falls	Organic peat soil	Black spruce uncut
		Black spruce selection
		Black spruce shelterwood
		Black spruce clear-cut patch
		Black spruce clear-cut strip

METHODS

At each plot, 10 sampling points were laid out and frost and snow data collected on each date of observation. The observations of snow accumulation and melt were published previously (Weitzman and Bay 1959), so this report will be confined largely to frost measurements — although both were collected concurrently.

After the first of each year, frost measurement was started and carried on into spring until the frost had completely left the ground. Measurements were taken at intervals of about 3 weeks except during the melt period when the intervals were closer.

On each sampling date, frost type and depth were recorded. Frost type was identified by chopping small pits. Depth was measured directly. Several types of frost were recognized, not all of which prevent the infiltration of water. In comparison to concrete frost, other forms known as granular, stalactite, honeycomb, and porous-concrete are much more permeable and less likely to cause excessive surface erosion (Dreibelbis 1949, Post and Dreibelbis 1942). Since the purpose of this study was to determine the hydrologic significance of frost, only concrete frost, which is least permeable to the passage of water, is reported. The frequency of occurrence is an average of all observations, whether or not concrete frost was present. The frost depths are an average of the inches of frost observed whenever it was present.

Where the frost was deep, a penetrometer was used and pounded to a depth of 10 inches (Stoeckeler and Thames 1958). Beyond that depth the penetrometer often bent, thus limiting the depth of observation. Available time and value of data did not justify deeper hand excavations. Throughout the 2 years about 2,800 frost observations were made.

RESULTS

The results of this study may be logically explained in simple terms. Soil freezing requires two basic ingredients — free water and freezing temperature. When the effects of cover type, soil texture, and snow depth on these two ingredients are examined, the reasons for variations in soil freezing are more apparent. Although other factors are involved (Anderson 1946, Tsytovich and Sumgin 1937), they do not prevent a firm interpretation of results.

The factors studied are divided into two broad groups — natural factors, over which we have no control, and management factors, which land managers can manipulate.

Natural Factors

Climate and soil play a major role in soil freezing through their effect on available soil moisture and soil temperatures. Although we have no control over these factors, their influence must be understood to show the framework within which management can operate.

Effect of Snow Depth

Under similar temperature conditions, the depth of snow strongly influences the amount of freezing. Snow is a good insulator. The very slow heat exchange between the atmosphere and the ground protected by snow is a result of poor heat conduction by the snow mantle. The deeper the snow, the more effective the insulation (Anderson 1947, Molchanov 1950).

Previous studies have indicated a correlation between snow depth and the occurrence and depth of concrete frost (Atkinson and Bay 1940, Sartz 1957, Scholz 1938). Most of these, however, were made on areas of different forest covers — or in different years.

The direct influence of snow on freezing was observed under identical conditions and cover during the winter of 1958. Six subplots were laid out in each of two cover types — an aspen stand and a red pine stand. On three subplots all snow was shovelled off; the other three remained undisturbed and snow was allowed to accumulate. Maximum snow accumulation reached only 10 inches. The difference in frost depth between the two treatments was tested on the last date shown, since this is the time of the year when frost is most important hydrologically; i.e., during spring breakup. The depth of concrete frost was significantly less (at the 5-percent level) in the undisturbed stands than in those where the snow had been removed (table 1).

TABLE 1. — *Average depth of concrete frost with and without snow cover (In inches)*

Date	Snow removed		Undisturbed	
	Aspen	Red pine	Aspen	Red pine
Dec. 17, 1957	0.7	4.4	0.4	3.9
Feb. 4, 1958	10+	10+	5.0	10+
Mar. 12, 1958	10+	10+	7.8	7.0
Apr. 3, 1958	10+	10+	5.9	5.5

Although snow accumulation is listed as a natural factor, the forest manager can manipulate to some degree the depth of snow that accumulates. Practices such as thinning conifers and planting alternate belts of mixed conifers and hardwoods will increase the amount of snow accumulated on the ground and thus help reduce soil freezing.

Effect of Soil Texture on Freezing

Most studies of freezing have concentrated on cover effects almost entirely, with no stratification by forest soils. Actually, soil texture affects moisture available for freezing, just as snow and forest cover modify temperature (Surmach 1955).

Since both moisture and temperature are equally important in freezing, a knowledge of soils helps explain the type and depth of freezing. Table 2 shows for 2 years the difference in frost occurrence under two soils of different texture. In both years there was more freezing in the heavier textured soil. It is suggested that texture modifies the amount of water held in pore space and limits availability of water for freezing. Sandy soils will freeze rapidly but, because water may be lacking, will not always form an impervious concrete frost in northern Minnesota. Silt loams, on the other hand, hold two to three times as much water. This becomes available for freezing under the right temperature conditions. As a result, concrete frost, which is a mass of consolidated ice crystals, forms throughout this type of soil mantle.

TABLE 2. — *Frequency of concrete frost by soil texture and cover (In percent)*

Year	Very fine sandy loam		Loamy fine sand	
	Aspen stand	White pine stand	Aspen stand	Jack pine stand
1957	68	53	5	6
1958	45	50	10	25

In this study a different type of frost was recognized. This type is almost as hard as concrete frost, but crumbles when dug into or chopped. The soil is hard but is not cemented together into a concrete-like mass by frozen ice crystals. One possible explanation is that an extremely low moisture content in sandy soils may prevent the formation of solid concrete frost. Pore spaces may be so large and moisture content so low that the ice crystals cannot form a continuous frozen lens.

This explanation is supported by the data on moisture content of frost types shown in table 3. Although the data vary considerably, the trend from low moisture content of nonfrozen soil to medium for dry concrete and extremely high for concrete frost is evident. A similar relationship was observed and reported in a companion study of infiltration in frozen soils (Stoeckeler and Weitzman 1960).

The combination of low local precipitation (average annual 25 inches) plus the low water-holding capacity of sandy soil is probably the reason for less concrete freezing in this area. Where precipitation is higher, there is apparently enough moisture even in sandy soils to freeze solidly (Striffler 1959).

The occurrence of dry or porous concrete frost varies with the precipitation pattern within any one year. For example, less of this frost type was recognized in the winter of 1958 because more rain fell and soil moisture was higher in the fall of 1957 prior to freezing than in 1956.

Freezing in Organic Soils

Freezing in organic soils has received very little study. Current tests in black spruce stands, both cut and uncut, indicate that peat soils probably follow the same freezing pattern as mineral soils. These observations were made on only one peat type. The peat was derived mostly from mosses, wood, and other plants. "Feather" mosses dominated the ground cover before cutting. Decomposition increased with depth below the surface. The ground water table was normally 6 to 30 inches below the surface. Peat depth averaged approximately 4 to 5 feet in the area.

It is logical to surmise that there is a range of conditions that modifies frost behavior in organic soils just as in mineral soils. Type of peat, depth to water table, and rate of flow through the peat

TABLE 3. — *Moisture content of frost types in sandy soils, 1957 (In percent by weight)*

Cover type	Frost type and date of measurement					
	Nonfrozen		Dry concrete		Concrete frost	
	Mar. 18	Mar. 26	Mar. 18	Mar. 26	Mar. 18	Mar. 26
Open plot	(1)	(1)	11.4	16.2	32.5	35.6
Aspen stand	7.5	7.1	23.5	16.5	53.8	(1)
Red pine stand (60 sq. ft. B.A.)	8.6	12.5	21.4	15.1	33.8	54.6
Red pine stand (140 sq. ft. B.A.)	(1)	9.1	12.2	21.6	27.4	45.1

1 *No measurements taken.*

bog all affect the heat exchange and probably the moisture in the upper horizons, both of which will affect the type of freezing. However, for the two seasons studied, the seasonal pattern of freezing followed the same trends as that of mineral soil.

Figure 1 compares the trends of concrete frost depth between February and April, 1958, under dense black spruce on peat, white pine on loam, and aspen on sand. In general, the patterns of freezing and thawing were similar. Frost in the peat, however, remained much longer than in mineral soil. There was still frost in the bog at the time of the last observation. Pieces of solid ice were found in late May and early June.

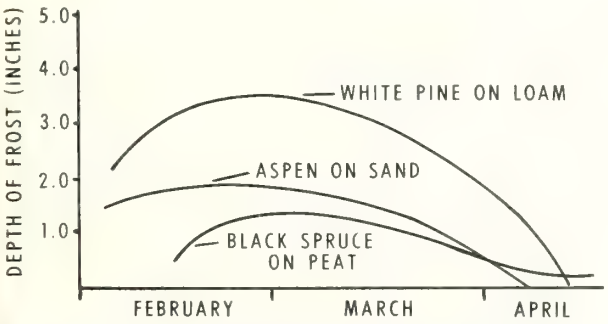

FIGURE 1. — Freezing pattern shows similar trend on mineral and organic soil; winter, 1958.

Management Factors

The natural factors, such as climate and soils, provide the framework within which freezing occurs. However, foresters manipulate other factors that can influence the free water and freezing temperatures and thus influence depth, type, and duration of freezing.

The effect of conventional forest treatments on soil freezing remains largely unexplored. Yet this is one of the few tools that foresters have to modify frost depth and duration. This study gives some indications on how the manipulation of cover will influence freezing.

Forest Versus Open

The advantages of forest cover over open land in reducing freezing are well established (Kienholtz 1940, Lull and Pierce 1961). The present observations show a similar trend (tables 4, 5, and 6).

TABLE 4. — *Depth of concrete frost during midwinter period (January to mid-March) on loamy soils (In inches)*

Cover type	1957	1958
Open plot	10+	10+
Forested plots		
Aspen (80 sq. ft. B.A.)	4.6	6.6
Aspen (65 sq. ft. B.A.)	3.7	5.8
White pine-hardwood	3.2	5.3
Balsam fir	7.4	10+
Red pine plantation	6.4	10+
Aspen-brush	3.6	6.4

TABLE 5. — *Frequency of occurrence of concrete frost on sandy soils (In percent)*

Cover type	1957	1958
Open plot	87	100
Forested plots		
Aspen	47	73
Red pine, 60 sq. ft. B.A.	44	66
Red pine, 140 sq. ft. B.A.	47	63

TABLE 6. — *Depth and frequency of concrete frost in black spruce bog, 1957*

Treatment	Depth	Frequency
Open plots	Inches	Percent
Clear-cut patch	3.4	77
Clear-cut strip	3.7	68
Shelterwood	3.5	58
Average	3.5	68
Forested plots		
Tree selection	2.0	35
Check	1.5	17
Average	1.7	26

The influence of forest openings on depth and duration of freezing in peatland is also very pronounced (table 6). In the three openings created in a black spruce bog, concrete frost occurred three times as often and was twice as deep as in the two test areas under forest cover.

Comparison of Cover Types

On loamy soils, the lowest incidence and the shallowest depth of frost were found under a mixed white pine-hardwood stand (table 4). This mixed stand had the deepest humus and the deepest accumulation of snow. These two factors both provide insulation against extreme soil temperatures and probably were responsible for the lower incidence of frost (MacKinney 1929, Striffler 1959).

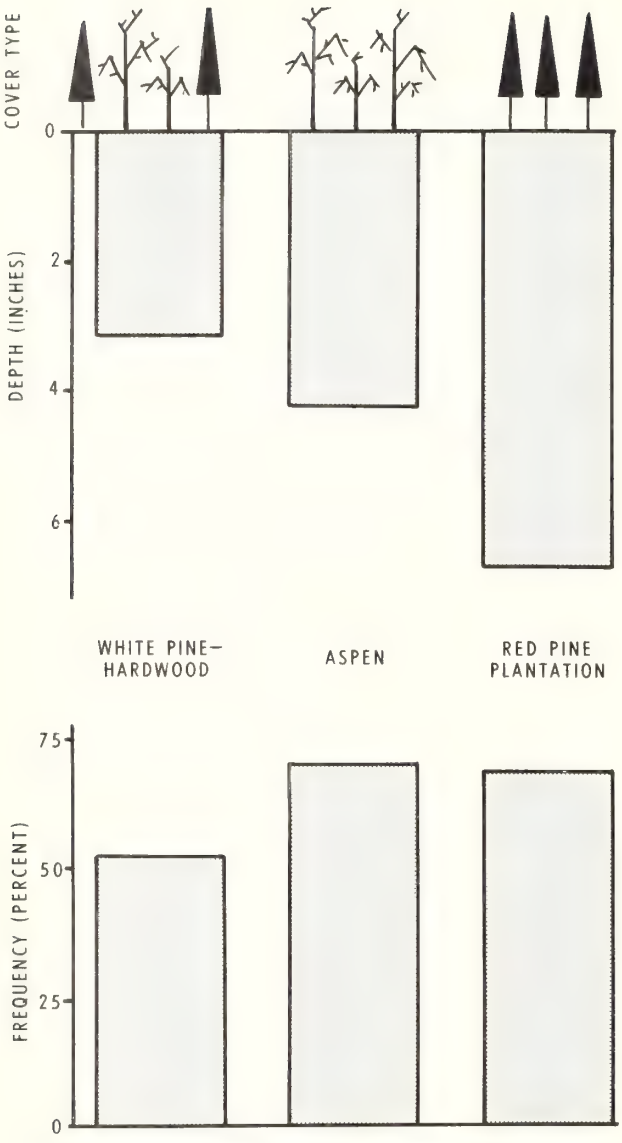

FIGURE 2. — Average depth and frequency of concrete frost under several cover types on loamy soils (1957).

TABLE 7. — *Depth and occurrence of concrete frost under two levels of red pine stocking, 1957*

Date	Thinned stand (60 sq. ft. basal area)		Unthinned stand (140 sq. ft. basal area)	
	Depth	Occurrence	Depth	Occurrence
	Inches	Percent	Inches	Percent
Jan. 7	4.4	100	6.5	100
Feb. 4	1.3	70	3.5	40
Feb. 18	1.7	60	3.0	60
Mar. 4	1.1	60	1.8	80
Mar. 18	1.9	90	1.9	70
Mar. 25	1.7	30	1.7	50
Apr. 1	1.3	30	1.7	50
Apr. 8	0	0	2.1	40
Apr. 15	0	0	1.7	20
Average	1.9	49	2.6	57

A pure pine planting, on the other hand, showed a greater depth of concrete freezing than either the mixed stand or pure aspen (table 4 and fig. 2). The incidence of concrete frost was lowest in the mixed stand and somewhat higher in both pure pine and aspen. Establishing a pure conifer planting on open, plowed, or burned-over land must be recognized as only the first step in soil amelioration. The pure conifer planting may be better than open-land areas, but not as good as the natural hardwood or mixed pine-hardwood forest.

Effect of Thinning in Dense Conifers

On sandy soils there was a slight decrease in depth of frost under a pine stand after thinning (table 7). The reason for the difference probably lies in the increased depth of snow accumulated in a thinned stand. Since snow is a good insulator, the temperature at soil level is higher, and hence the freezing is reduced.

Thinning dense conifers is accepted as a sound management practice. This study indicates that it may have some hydrologic benefits as well. The thinned pine stand accumulated more snowfall and had less frost depth to impede water infiltration into the ground.

Effect of Thinning in Aspen

A thinned aspen stand on loamy soil also showed a small reduction in frost — both depth and occurrence (table 8). The difference again was not large, and the same factors were probably involved.

TABLE 8. — *Depth and occurrence of concrete frost under two aspen stands with different levels of stocking, 1957*

Date	65 sq. ft. basal area		80 sq. ft. basal area	
	Depth	Occurrence	Depth	Occurrence
	Inches	Percent	Inches	Percent
Jan. 9	1.8	70	1.9	90
Feb. 5	4.2	80	4.2	100
Feb. 19	2.7	90	5.1	100
Mar. 4	3.5	100	6.5	100
Mar. 22	5.9	90	5.4	100
Apr. 4[1]	2.7	70	5.5	90
Average	3.5	83	4.8	97

[1] *On the next date of measurement, April 11, no frost was found.*

SUMMARY

The study indicates that snow depth, soil texture, and cover type and density are related to depth and duration of soil freezing. Many other factors must be studied before the full and composite effect of forest cover and its manipulation are understood. Nevertheless, the results of these observations indicate the conditions that reduce ground freezing and thus provide an opportunity for water to enter the soil rather than run off in spring freshets.

1. Frost depth and duration varied from year to year, depending on natural climatic factors such as moisture in soil and snow depths.

2. Sandy textured soils had less concrete freezing than fine-textured soils that retain more water.

3. The pattern of freezing in an organic soil was similar to that of mineral soils, but frost lasted much longer in organic material.

4. Thinning in a conifer and a hardwood stand slightly reduced the depth and duration of frost, largely because of a greater accumulation of snow which acts as an insulator.

5. Freezing under hardwoods was less severe than under conifers.

6. A mixed stand of scattered conifers and hardwoods (white pine-hardwoods) combined the advantages of the lowest incidence of frost and the greatest accumulation of snow. Thus a mixed stand is more desirable than pure stands of either pine or hardwoods for reducing frost.

7. Open areas had greater depth and duration of concrete frost than forested areas.

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FEBRUARY 1963

EUGENE I. ROE

Direct Seeding of Conifers in the Lake States:

A REVIEW OF PAST TRIALS

Direct-seeded jack pine 10 years old and 15 feet tall

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CONTENTS

Page No.

EARLY WORK 1

AURORA JACK PINE SEEDING 2

SUBSEQUENT SEEDING TRIALS 3

- Jack Pine 3
  - Cone scattering 3
  - Broadcast seeding 4
  - Seed spotting 5
  - Seeding with handtools 6
  - Drill seeding 7
  - Special seedbed studies 7
- Red Pine 8
- White Pine 9
- White Spruce 9
- Black Spruce 10
- Balsam Fir 10

AERIAL SEEDING 11

SEED REPELLENT TREATMENTS 12

GENERAL CONCLUSIONS 12

LITERATURE CITED 14

FOR YOUR REFERENCE FILE

Four abstract cards are included at the back of the report for the reader's convenience.

Direct Seeding of Conifers in the Lake States: A Review of Past Trials

By Eugene I. Roe[1]

During the past 2 or 3 years, there has been a considerable renewal of interest in direct seeding in the Lake States. This has been brought about partly by the soaring cost of forest planting and partly by the excellent results being obtained with aerial seeding of pines in the deep South (Derr and Mann, 1959; Mann and Derr, 1961).[2]

As a result, various agencies have installed small-scale exploratory seeding trials, and others have shown much interest in such tests. Since a coordinated, cooperative effort should produce quicker results than the individual approach, a regionwide meeting of those interested was held at Grand Rapids, Minn., on March 13, 1962, to exchange views and to decide on needs.

For background, much of the material in the following report was presented. Since then, other tests made in the Lake States and Canada have come to light, and these have been added. Any trials made since 1958 are not included in the review.

Despite the title of this paper, direct seeding in the Lake States has not been limited to coniferous species. Some work has been done with hardwoods, particularly with the seeding of oaks and basswood in Wisconsin. But there is little interest at present in the forest planting of such hardwoods and even less in seeding them. So they will be mentioned only in passing in this report.

EARLY WORK

Interest in direct seeding in the Lake States and adjacent Canada goes back at least 40 years.[3] In 1937, Shirley summarized the work that had been done on the National Forests and elsewhere in the Lake States region. Briefly, he reported as follows (Shirley, 1937):

Since 1926, when the first known trial was made, some 130 different seedings had been tried in the three Lake States, using 20 distinct methods and involving 18 species. Some of these must have been on a sizable scale, for their aggregate area was over 300 acres.

Methods tested, all on upland, mostly sandy soils, included different kinds of site preparation and seeding methods in both fall and spring. Seed was sown:

1. Without site preparation
2. On land that had been plowed either completely or in part
3. On soil that had been exposed by disks or spring-tooth harrows
4. On burns, both after wildfire and prescribed burns
5. On scalps
6. On spots prepared so as to provide shade or make them inconspicuous to birds and rodents.

Seeding methods included:

1. Broadcast sowing
2. Spotting with and without covering
3. Drilling the seed by hand or with small seeders such as the Planet Jr. garden seeder.

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[1] *The author is a research forester at the Lake States Forest Experiment Station. The Station is maintained by the Forest Service, U.S. Department of Agriculture, at St. Paul 1, Minn., in cooperation with the University of Minnesota.*

[2] *Names and dates in parentheses refer to Literature Cited at the end of the report.*

[3] *Except as otherwise indicated, tests of direct seeding in the northeastern United States and in eastern Canada have not been included because of the great differences in climate between those regions and the Lake States.*

Most of the tests did not attempt to protect the seed against rodents and birds. In a few areas poison bait had been distributed; in others seed spots were covered with conical screens; and on still others, the seed was dusted with red lead or sprayed with sulphonated linseed oil. Occasionally, a light dressing of alum was used to reduce losses from damping off.

The species tested included all of our commercial northern conifers except black spruce and hemlock, eight hardwoods (including two oaks, yellow birch, basswood, and white ash), and the exotic conifers, ponderosa and Scotch pines, Norway spruce, and European larch.

Shirley examined most of the seeded areas in the fall of 1936. He found that, although 60 percent of the seedings had shown better than 50-percent stocking at the end of their first year, only 15 percent of the areas were still so stocked. Much of the loss had been caused by the severe summer droughts of 1933, 1934, and 1936. Other important factors were lack of site preparation, destruction of the seed by rodents and birds, and failure to release the seedlings in their early years from the competition of grass, herbs, and brush. In some species, germination had been poor because no pretreatment was given the seed.

Seedings of only three species, jack pine, red oak, and bur oak, had been successful and these only on sites free from both aggressive competition and seed-destroying rodents and also receiving abundant, well-distributed rainfall during the first two growing seasons. Seedings of all other species had failed. Shirley, therefore, concluded that direct seeding was a poor substitute for planting.

AURORA JACK PINE SEEDING

Shirley's unfavorable report, however, did not prevent the installation of what is probably the most ambitious seeding job yet attempted in the Lake States. During August 1936, the Aurora Ranger District of the Superior National Forest had a 30,000-acre fire which completely destroyed the powder-dry layer of heavy duff and reduced the rodent population to practically none. Two of the basic requirements for a successful seeding were, therefore, present. Since the Forest had a supply of jack pine seed — the most promising species for direct seeding in the Lake States — the Forest officers decided to take a chance on the weather conditions and sow as much of the burn as possible.

Seed was broadcast with Cyclone seeders on the crusted snow of three forties in late March and early April 1937, and about 155 acres of bare ground were sown during early to late May. Part of the latter area was harrowed with a spike-harrow both before and after seeding, some was harrowed after seeding, and the rest had no soil-surface treatment. Three pounds of dry seed were sown per acre on all blocks, as prior tests had indicated only about 20-percent germination (Roe, 1951).

Fortunately, the drought broke. Rainfall in the 1937 growing season was abundant and well distributed, and maximum temperatures were not as high as in 1936. As a result, all areas showed a stocking of 9,000 to 13,000 seedlings per acre that fall except for the snow seedings, which were virtual failures. Subsequent years were also favorable, and the seedlings developed so rapidly that no release measures have ever been needed. Although considerable mortality has occurred, the stands have been so dense from the start as to present a thinning problem (fig. 1). Apparently, the seed had been of considerably better quality than was realized. One pound per acre would likely have proved sufficient, and the investment in soil treatment (harrowing) only aggravated the thinning problem (Roe, 1951).

The score here is 155 acres of overstocked jack pine, 40 acres partially stocked, and 80 acres a failure. The poor areas are the three forties that were snow-seeded; the overstocked are those seeded on bare ground.

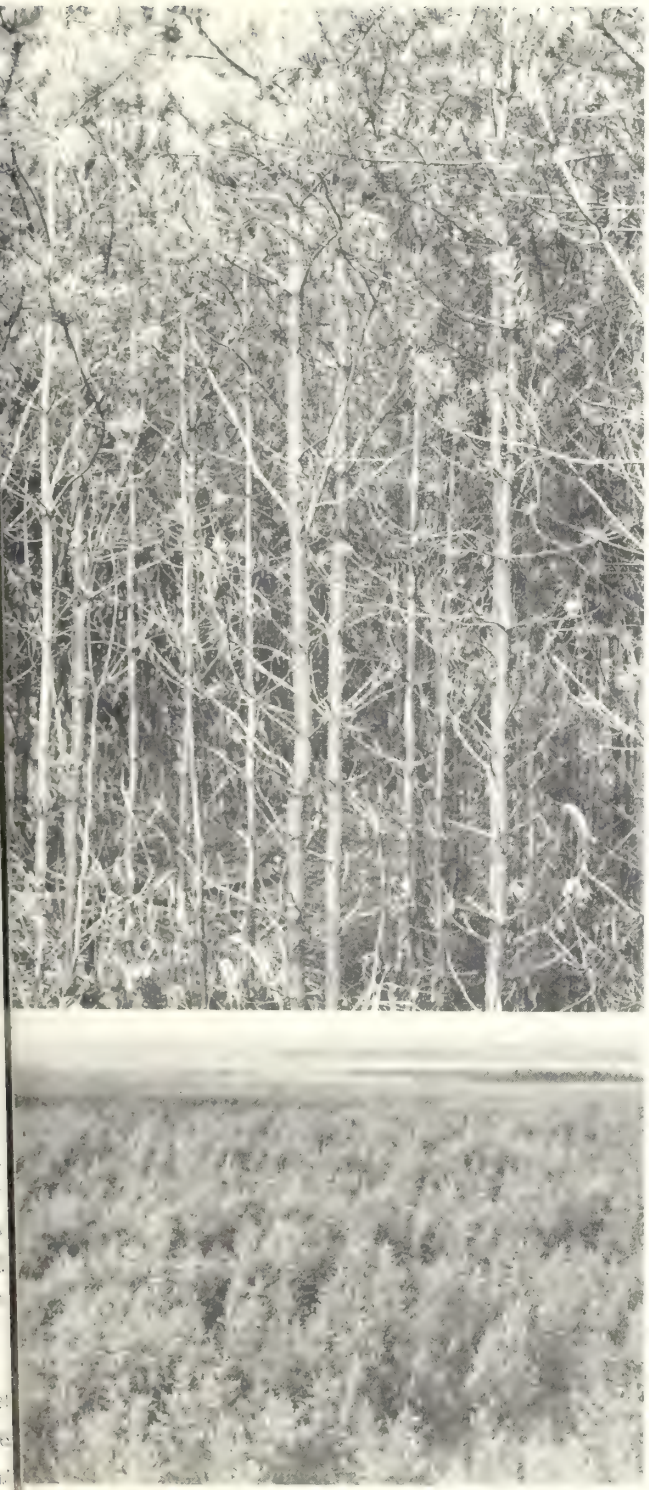

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FIGURE 1. — Two views of the Aurora jack pine direct seeding. In 1936 the area was burned over by a wildfire, destroying the layer of heavy duff as well as the rodent population. A broadcast seeding was made in spring 1937. Ten years later the area seeded on bare ground averaged 10,600 seedlings per acre.

SUBSEQUENT SEEDING TRIALS

The success of the seeding at Aurora did not arouse much general interest, probably because it was given little publicity. It likely was responsible, however, for at least some of the seeding trials put in by various members of the staff of the Lake States Forest Experiment Station in the late 30's. These and subsequent tests in the 40's and 50's were mostly with jack pine, but a few trials were also made with red pine, white pine, white spruce, black spruce, and balsam fir. Some were made in Minnesota on the Chippewa and Superior National Forests, and some in Wisconsin and Michigan.

Canadian foresters have also been interested in seeding, in fact, even longer than we in the Lake States. Their early studies, however, were reported only recently and are included here (Cayford, 1959; Haig, 1959).

The general details of these various trials are given by seeding methods under species. Others may have been installed, but they have not been reported in the common channels used for forestry publications.

The results of the seedings have been rated as to success in three groups, good, fair, and poor-to-failure, on the basis of the criteria shown in table 1. The standards set up are somewhat lower for spruces and balsam fir than for pines. This is because the spruces and balsam fir can stand more suppression and also tend to fill in by means of early self-seeding.

Jack Pine

The many trials of direct seeding with jack pine in the Lake States and adjacent Canada include almost all of the possible combinations of seeding methods and site preparation. They cover sites from eastern Ontario to western Manitoba. For convenience, they are grouped by the following seeding methods: (1) cone scattering, (2) broadcast seeding, (3) seed spotting, (4) seeding with hand tools, and (5) drill seeding.

Cone Scattering

Cone scattering or its variant, the scattering of cone-bearing slash, is being used successfully on disked or rock-raked ground to restock cutover jack pine lands on the Superior National Forest and elsewhere. Several pilot-scale applications are

TABLE 1. — *Criteria used to determine success in Lake States direct seeding trials*[1]

Results	Age of seeding	Jack, red, and white pine		Spruces and balsam fir	
		Stocking	Seedlings per acre	Stocking	Seedlings per acre
	Years	*Percent*	*Number*	*Percent*	*Number*
Good	2-3	60+	1800+	60+	1500+
	4-6	50+	1000+	50+	750+
	7-10	50+	700+	40+	500+
Fair	2-3	30-60	800-1800	30-60	500-1500
	4-6	30-50	500-1000	30-50	400-750
	7-10	30-50	400-700	30-40	300-500
Poor to failure	2-3	30—	800—	30—	500—
	4-6	30—	500—	30—	400—
	7-10	30—	400—	30—	300—

[1] *Adjustment in rating was occasionally made for trials with appreciably higher stands of seedlings but lower stocking than the values shown and vice versa.*

underway on the Tomahawk Sale. Since the cones open at different times, depending on their distance from the ground, the amount of shade, and other elements affecting their temperature, cone scattering has the advantage of making the seed available for regeneration for a much longer period — 2 to 3 years or more — than when seed alone is used.

This treatment on a disked area on the Kawishiwi Experimental Forest in northeastern Minnesota produced a stand of 4,300 jack pine seedlings per acre with 61 percent stocking at the end of the second growing season.[4] Cone scattering has shown fair results in Manitoba (Cayford, 1959).

Broadcast Seeding

Scattering the seed broadcast has been used more extensively with jack pine than has any other seeding method. Tests have been made on fresh burns and on sites prepared by mchanical means, using seed broadcast both in late winter on snow and during the growing season.

On burns. — Seeding on top of snow in late winter at Aurora, as already pointed out, was a failure (Roe, 1951). Seeding on bare ground, on the other hand, has generally turned out much better. On the Chequamegon National Forest in Wisconsin, seeding on a fresh burn proved successful (Stoeckeler and Limstrom, 1950); and another one on the Chippewa National Forest, using only ¼ pound of seed per acre a few days after a fire in late April 1949, gave good results. On the credit side, also, are the broadcast seeding at Aurora (Roe, 1951) and one that Shirley (1937) considered a failure, likely because he did not have full information on it. The latter, a 1.5-acre tract on the Kawishiwi Experimental Forest in northeastern Minnesota, was clearcut and burned in early July 1935. Strips seeded to jack pine in mid-May 1936 at 2 pounds per acre were then gone over lightly with a Rich fire tool. These showed 4,900 seedlings per acre and 83 percent stocking that fall after going through the 1936 drought. It is still a fully stocked stand.

Only partly successful, however, was the 122-acre seeding in June 1948, following a severe fire on the Tofte District of the Superior National Forest (fig. 2). The first block was sown to about 3 pounds of seed per acre; subsequent blocks averaged 1 pound. Duff consumption had been quite complete. A good rain had fallen at the completion of the job, but little occurred during the next 3 or 4 weeks. The results at the end of the second year follow (unpublished data):

Site:	*Area (acres)*	*Stocking (percent)*	*Seedlings per acre (number)*	*Sowing rate (pounds/acre)*
Upland	10	64	1,750	3.1
Semi-swamp	1	80	3,700	1.0
Upland	111	26	505	1.0

Even poorer were two other trials made on the Superior, one sown with a small amount of seed right after burning in spring 1942, the other with ⅜ to ½ pound of seed per acre in late May 1945 after a burn the preceding November. Both failed,

[4] *Much of the material given in this report is based on unpublished data in the files of the Lake States Forest Experiment Station. In the remainder of the report the reader may assume that test results not referenced to a specific literature citation are gleaned from unpublished Station data.*

likely because of poor destruction of the heavy duff and insufficient seed.

On mechanically prepared sites. — On most of the areas broadcast-seeded after mechanical treatment of the site, the ground was prepared with light farm disks in the earlier years and with the heavier Athens disks in later years (fig. 3). The first known trial of mechanical site preparation was made on the Duck Mountain Forest Reserve in western Manitoba in 1920 but was not reported until recently (Haig, 1959). Like most of the many subsequent trials, this involved seeding on bare ground and consisted of three ¼-acre plots broadcast-sown in May with 2, 3, and 4 pounds of jack pine seed per acre. Early results were excellent, but hare nipping in 1924 and again in the early 30's eventually wiped out the seedlings.

Canadian foresters have done considerable additional work of this type on the Sandilands Forest Reserve not far north of the Minnesota border. These seedings, totaling about 400 acres and put in during the periods 1925-28, 1943-45, and 1950-55, were described recently by Cayford (1959). Seed was broadcast from early April to mid-July and also in October at rates varying from 0.2 to 2.0 pounds per acre. Generally, the results were good. Ratings made 3 to 13 years after seeding showed that 19 of the 30 trials were well stocked — some were greatly overstocked as at Aurora (Roe, 1951) — 2 had fair stocking, and 9 were poor-to-failure.

On the Chippewa National Forest, broadcasting 1 pound of jack pine seed in late April 1940 on an area disked the preceding fall showed fair stocking the first year but poor results 3 years later.

A few trials of broadcast-seeding jack pine on disked sites have also been put in on snow in late winter. One such seeding with 0.8 to 1.6 pounds of seed per acre made in southeastern Manitoba in early April 1953 gave a well-stocked stand of seedlings (Cayford, 1959). But on the Chippewa, such seeding at 1 pound per acre both in mid-winter and in late winter (early to mid-April) 1940 showed poor results.

Seed Spotting

Seed spotting has been tested on prescribed burns, on disked or furrowed areas, and on unprepared sites. One test was begun in May 1942 on the Superior National Forest on a small area that had been burned the preceding fall. Seed was sown both with and without soil covering. Uncovered seed for some reason gave better results, showing 2,600 seedlings per acre and 70 percent

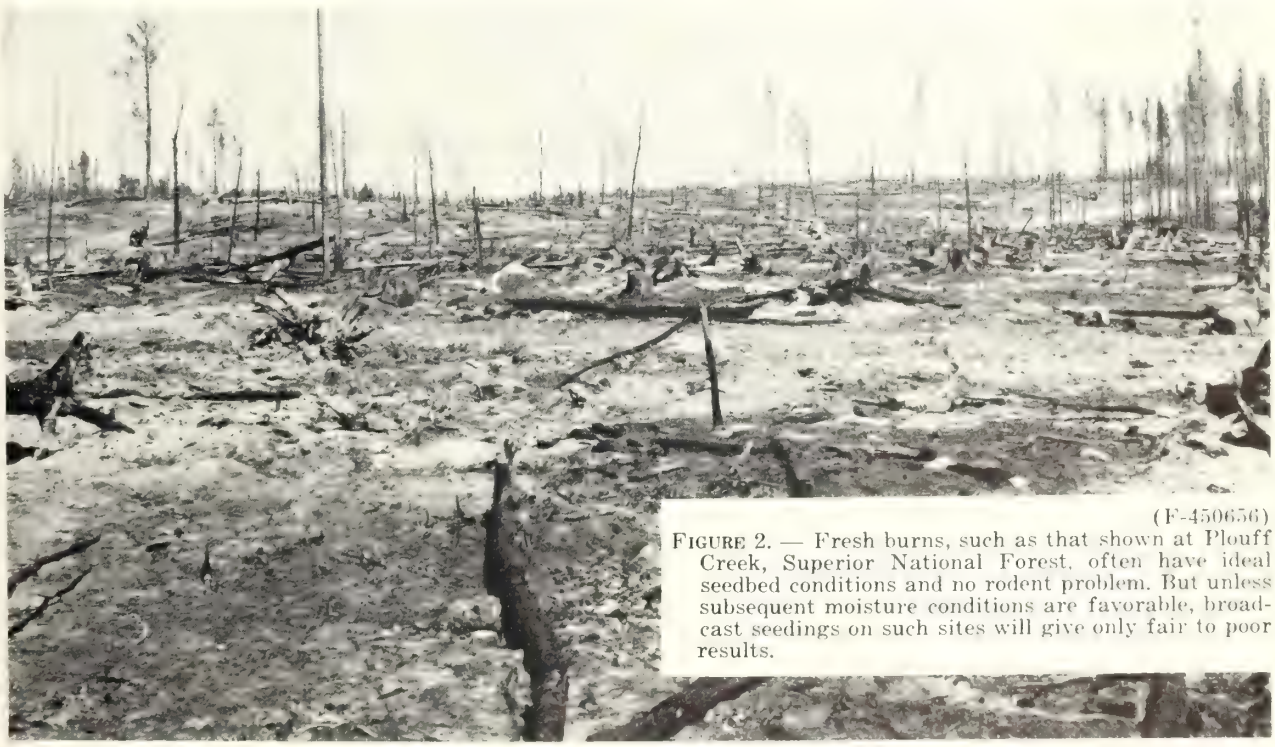

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FIGURE 2. — Fresh burns, such as that shown at Plouff Creek, Superior National Forest, often have ideal seedbed conditions and no rodent problem. But unless subsequent moisture conditions are favorable, broadcast seedings on such sites will give only fair to poor results.

stocking at the end of the third year compared to 1,550 seedlings and 50 percent respectively for covered seed.

Another test made in Ontario showed good stocking (77 percent) at the end of 4 years from both fall- and spring-sown jack pine which had been seeded on screened spots in a burn. Unscreened spots, on the other hand, were failures (Leslie, 1953).

Several attempts have been made to seed-spot jack pine on land that had been previously disked or furrowed. One test on an area of disked soil on the Chippewa National Forest failed the second year, likely because of the re-invasion of grass. Also a failure were trials in Manitoba of seed spotted in the bottom of furrows in June and November 1952 (Cayford, 1959). On the other hand, seed spotting after disking in jack pine clearcuttings showed much better results. Of four trials, one turned out poorly, but the other three showed 900 to 1,600 trees per acre with 45 to 60 percent stocking 7 to 9 years after seeding (Cayford, 1959).

Seed spotting on unprepared sites has generally been ineffective. Two tests made on the Superior in a jack pine clearcutting showed only a poor stocking at the end of 3 years, but a test in similarly cut jack pine in eastern Ontario had excellent results (Logan, 1951b). Trials made on both open sand plains and under adjacent poor-site aspen, also in eastern Ontario, failed (Horton and McCormack, 1961), as did six of eight ¼-acre plots so seeded on open jack pine land in Manitoba in the late 20's. Of the remaining two plots, one plot 3 to 6 years after seeding had a fair stand while the other was well stocked (Cayford, 1959).

Seeding With Handtools

At Aurora, a 1-acre tract burned in the fire of 1936, was seeded in 1937 with an Efco rake. This tool, resembling a potato hook, has a hollow handle containing the seed. After a spot is prepared with the rake, a few seeds are released and worked into the soil.

Germination was good and survival high, the plot showing 2,200 seedlings per acre at the end

(F-471816)

FIGURE 3. — Disked areas are also excellent seedbeds when moisture conditions are adequate, but they must be protected from rodents.

of 4 years. Many spots, however, had two to nine seedlings. Since most of these were still alive at 10 years, thinning was needed (Roe, 1949a). To be satisfactory, a tool should be designed to deliver fewer seeds per spot.

In 1953, the Station made a rather thorough trial of the Baker seeding tool. This was tested with jack pine and red pine seeds at six different locations on the Tomahawk Sale on the Superior National Forest. Seed was sown in May, June, July, September, and October on duff and on scalped spots with and without screening against rodents. Although the results were generally poor, some differences were evident; these were (Strothmann and Conover, 1960):

1. Spring and summer seedings of jack pine were better than fall seeding.
2. Scalped spots showed no consistent advantage over unscalped spots.
3. Screening was definitely beneficial.
4. Best results were obtained from the May and June seedings on an area that had been logged one year previously.

Drill Seeding

Drill seeding in furrows, using such machines as the Planet Jr. garden seeder, has been tested on both large and small tracts on the Nicolet National Forest in Wisconsin and the Chippewa in Minnesota (fig. 4). A large seeding on the Nicolet in the spring 1937 failed mostly because of drought, but heavy losses were also caused by smothering of the seedlings by leaf litter during the following winter (Stoeckeler and Limstrom, 1942). A detailed examination the second year showed a striking relation between stocking and depth to the water table. Areas where this was at 2 to 3 feet in midsummer had 4,000 to 6,000 seedlings per acre compared to 1,200 or fewer where the water table dropped below 4 feet. Subsequent trials on a small-plot scale showed fair and poor stocking at the end of the second season for fall and spring seedings, respectively. Losses were due mostly to lack of protection against rodents (Stoeckeler and Limstrom, 1942).

Large-scale drill seedings on the Chippewa showed variable results. One seeding put in in the spring of 1938 proved overstocked, but a repeat that fall failed as did one in the spring of 1939 and much of an even larger seeding made in the spring of 1942. Moisture conditions had been generally favorable; the failures were due mostly to washing and covering of the seedlings or to closing over of the furrows by side vegetation.

Special Seedbed Studies

In addition to trials of the various seeding methods, most of which were empirical, two seedbed studies deserving mention have been conducted.

The first of these, made by LeBarron (1944) in northeastern Minnesota, tested the germination and early development of jack pine and black spruce seeds and seedlings over a 2-year period. The trials included different types of seedbeds under different degrees of tree and low cover,

(F-273313)
FIGURE 4. — In one of the early seeding trials, grooves made with a wheel in the bottom of shallow furrows were seeded by hand.

both with and without protection against rodents and birds. Both species germinated best on bare mineral soil; results were less satisfactory on burned duff and scarified shaded surfaces and poor on undisturbed duff. Growth of the seedlings, however, was poorer on the bare soil than on the other three surfaces. In years with normal summer rainfall, growth was favored by the absence of both tree and low cover. The chief cause of mortality to seedlings was insects, mostly through defoliation. Damping-off fungi ranked second; heat, third; and drought, fourth. The importance of birds and rodents as seed-destroyers proved much smaller than expected.

In the second study, Beaufait (1960), working with jack pine in Lower Michigan, tested the effect of time of sowing on three different seedbeds under three light levels. He found that sowing early (late May) gave no advantage to the germinating seedlings over later sowing (mid- and late June). Although germination was best under one-third normal light, the seedlings showed poorer survival here than under either two-thirds light or full light. Of the different soil treatments, results on scarified soil were much superior in germination and survival than on burned and untreated soil.

Red Pine

Relatively little has been done in the Lake States with direct seeding of red pine. Most of the work consists of a few trials of seed spots on the Superior National Forest. Spots of five seeds each, covered with soil, were put in in the spring of 1944 on a disking that had settled over winter. These showed 65 percent stocking and 1,710 seedlings per acre the first year. By the ninth year, however, the stand was reduced to 24 percent stocking and 610 per acre, a fairly satisfactory stand.

Seed sown and covered in May 1947 on another settled disking, however, showed poorer results. Some had been water soaked, some stratified, and the rest not pretreated. Although the stratified seed germinated earlier, results of all treatments at the end of the first year were similar — 650 to 820 seedlings per acre and 30 percent stocking. At the end of the sixth year, stocking averaged only 19 percent and seedlings 425 per acre.

A third series of spots put in in May 1945 with covered and uncovered seed on an area burned for the purpose the preceding fall was a failure from the start. This was also true of another plot in the same burn on which 3 ounces of seed were broadcast per acre. Likewise, a 220-acre broadcast seeding (4 to 8 ounces) in a fresh burn on the Chippewa National Forest in May 1949 failed. In none of these trials was the seed protected against rodents.

In Wisconsin, Stoeckeler and Limstrom (1942 and 1950) compared fall versus spring seeding of red pine drilled in furrows. Results despite rodent losses the first year were fairly good; but subsequent losses, mostly from smothering of the seedlings by hardwood leaves, were heavy. At the end of the second year, stocking was only fair, and the seedings eventually failed.

A few seed-spot trials have also been reported from Canada, mostly from the Petawawa Forest Experiment Station. The earliest on record dates back to 1922 when covered red pine seed was sown on spots prepared in a 50-year-old aspen-birch stand that had been thinned to different intensities. Although survival 10 years later was fair, the seeding eventually failed because of the heavy competition from aspen suckers and hardwood sprouts (Fraser, 1952).

Later at Petawawa, a similar test was made in a jack pine clear cutting. This showed an excellent initial catch, but stocking dropped to 41 percent in 4 years and to less than 20 percent in 11 years. The losses were apparently due to the exposed open site (Logan, 1951b).

Poor results were also obtained from a test of covered and uncovered seed, sown with and without red lead treatment, on an open jack pine site and under an adjacent stand of light aspen. Only the seed sown under aspen and covered with ½ inch of soil showed fair stocking (40 percent) 5 to 6 years later; however, the seedlings had made but little growth. Seed protection was of some benefit (Horton and McCormack, 1961).

On the other hand, a test of seed spotting in the Port Arthur area was successful. Leslie (1953) cites excellent stocking at the end of 4 years from seed sown in a burn under screens, both in fall and spring; unprotected spots were a failure.

A test was also made with the Baker tool on the Superior on scalped and unscalped spots, with and without screening against rodents, in May, June, July, September, and October 1953. The results, generally poor, were best on scalped spots

that had been seeded in May or June and protected against rodents (Strothmann and Conover, 1960).

White Pine

Although white pine has a large seed and would thus seem to be an easier species to establish by direct seeding, little work has been reported on it. Most of this is from Petawawa where it was tested with the other native pines.

Seed spotted under an aspen-birch thinning there in 1922 showed fair to good survival 10 years later, but the seedlings were eventually choked out by aspen suckers and brush (Fraser, 1952). Fair early results were obtained from seed spots in a jack pine clear cutting in 1939, but the seedlings quickly failed and were a complete loss 7 years later, apparently because of the open site (Logan, 1951b). Seed sown in the 50's, both covered and uncovered, on an open jack pine site and under adjacent aspen of light stocking showed generally poor results except for the sowings under the aspen with a light cover of soil. These had about 45 percent stocking after 5 to 6 years, but the seedlings were so small that the job could hardly be considered fair (Horton and McCormack, 1961).

Another test at Petawawa involved seeding under 55-year-old white pine on small plots given the following surface treatments: exposed mineral soil, light burning, severe burning, and undisturbed duff. Since the seed was sown at the rate of one-half pound per milacre, the stand-per-acre figures have little meaning. When the test was closed at the end of 11 years, the best treatment was the severe burn. Exposed mineral soil was a close second, the light burn a poor third, and undisturbed duff poorest (Logan, 1951a). A test of white pine seed-spotting in a burn near Port Arthur was also successful where the spots were screened; stocking 4 years later was excellent for fall sowing and good for spring sowing. That on unscreened spots was poor for fall sowing and fair for spring sowing (Leslie, 1953).

In the Lake States only one test of white pine has been reported in recent years. This was a small trial of acid-treated seed made in Wisconsin. It showed high stocking on both screened and unscreened spots at the end of the first season but apparently failed later on (Stoeckeler and Limstrom, 1942, 1950).

White Spruce

The earliest direct seeding test known of white spruce was begun in Manitoba in May 1920. Seed was broadcast at 1, 2, and 3 pounds per acre on well-disked soil and then harrowed. The job was so successful that the ¼-acre plots still showed 3,400 to 5,000 seedlings per acre 27 years later and were in need of heavy thinning (Haig, 1959).

Similar seedings attempted in the Lake States have not turned out so well. One on the Chippewa National Forest, using 2 pounds of seed broadcast in November 1951 on snow on an area disked the previous summer, showed about 500 seedlings per acre with 30 percent stocking after the seventh year. Initial germination had been poor, probably because much of the seed eventually lodged on top of the litter from the hardwood overstory (70 square feet of basal area). There had also been heavy competition from herbs.

On the Superior National Forest, spotting the seed on a fresh disking in October 1945 showed fair to good results at the end of the first season where the seed had been covered with soil — 40 percent stocking and 1,500 seedlings per acre. But by the end of the sixth season, results were very poor, most of the loss having occurred during the first winter. On the other hand, seed spotting in May 1945 on an area burned the preceding fall gave results somewhat similar to those of the snow seeding on the Chippewa. At the end of the third season, stocking here averaged 30 percent and seedlings 625 per acre; results with uncovered seed were slightly superior to those with covered seed.

In the fall of 1938 white spruce was drill seeded in furrows in Wisconsin; this was a failure (Stoeckeler and Limstrom, 1942). Seed-spotting tests in Canada have also shown discouraging results. Leslie (1953) reports only fair results after four seasons from fall-sown, screen-protected seed, poor results for similar seed sown in spring, and a complete loss for unscreened seed; this trial was made in a burn. And seed sown in 1922 on prepared spots in a thinned aspen-birch stand showed poor survival (20 percent) 10 years later. Most of the loss was due to competition from aspen suckers and brush. The ability of this species to hang on under adverse conditions is brought out by the fact that, with no release, 11 percent of the spots still had 1 or more seedlings 26 years later, and these ranged up to 8 feet in height (Fraser, 1952).

Considerable light has been thrown on the seedbed requirements of white spruce by a study in northeastern Minnesota. Seed sown on three different types of seedbed in a clear cutting and under a medium overstory showed much the best germination and establishment on bare mineral soil. Results on duff were about the same as those on duff shaded by light slash. Survival at the end of 5 years was much superior under medium cover to that in the open (LeBarron, 1945).

Black Spruce

A few seeding tests of black spruce have been made both on upland and lowland. A replicated trial in Newfoundland in the spring of 1950 on a July 1949 burn showed trees averaging 1 foot in height at the end of 4 years, and the following stocking:

Broadcast seeded on snow, late April — 66 percent

Broadcast seeded on bare ground, mid-May — 29 percent

Seed pressed into bare mineral soil, mid-May — 54 percent

The good results are in large part due to the great amount of seed used — 11 pounds per acre. Germination, however, was only 40 percent (Dickson, 1956).

On the Superior National Forest, a broadcast seeding of 1 pound per acre in the spring of 1945 on a burn of the previous fall showed poor results the first year and had failed by the third season. However, seed spots put in at the same time gave much better results, particularly where the seed was covered with soil; these had 45 percent stocking and 700 seedlings per acre at the end of the third season. Another seed spotting on a fresh disking in the fall of 1945 got off to a much poorer start and had failed by the third year.

Seedbed studies made with this species in the forties show that on upland sites black spruce germinates best on bare mineral soil; burned duff and shaded scarified duff are less effective, and slash-shaded and undisturbed duff, poor. Survival and growth are better in the open than under partial tree cover or under low vegetation. Rodents were not important as a destructive agent; the chief causes of seedling mortality were various needle-eating insects, damping-off fungi, and heat (LeBarron, 1944, 1945).

Most of the lowland seeding trials of black spruce have been made on the Kawishiwi Experimental Forest. One in July 1947, consisting of pressing the seed with the foot into hummocks of live sphagnum moss in an open swamp, showed initial stocking of 96 percent. However, the fast-growing moss outgrew many of the seedlings during the first autumn, causing stocking to fall to 50 percent (Roe, 1949b). Little subsequent loss occurred; 5 years later stocking was 48 percent with the trees averaging 15 inches in height.

Further tests of this method, made in 1949 in the same swamp but earlier in the season and with smaller amounts of seed, had very poor results; the loss was due to moss smothering and to high water levels.

Subsequent trials were aimed at controlling the sphagnum competition with 2,4-D. These proved that the moss had to be sprayed well before seeding as the seedlings were injured by the herbicide. And if seeding was delayed too long, the moss would become re-established.

Since different sphagnum species seem to show differences in growth rate and other qualities affecting their value as seedbeds, this opens up an entire new field for study. Although the success ratio of lowland spruce seedings is low, the one good job suggests that seeding could well be a practical way of restocking swamps with black spruce (fig. 5).

Balsam Fir

Several trials with balsam fir have been put in on upland sites in northern Wisconsin and one or two in northern Minnesota. Most were seed-spotted either on disked land in furrows, in small openings in a hardwood stand, or under sprayed brush. On two areas, the seed was broadcast after disking. Two tests were also made of seed spotting on lowland.

Disked areas in poorly stocked aspen, in cut-over jack pine, and in heavy sod were spring-sown with stratified seed. In the first two conditions, some spots were covered with soil, others left uncovered; in the heavy sod, some spots were screened against rodents. The first-year results were fairly good under light aspen cover but poor elsewhere. The latter areas eventually failed, but the one under light aspen still showed 750 trees per acre and 30 percent stocking after 11 years. The trees had made little height growth, however (Stoeckeler and Skilling, 1959).

(F-452494)

FIGURE 5. — The possibilities of seeding black spruce in swamps need thorough study. These 2-year-old seedlings have outgrown the competing sphagnum moss and are well established.

In Wisconsin, spotting stratified seed in furrows proved a failure because of the eventual suppression of the seedlings by sod in the furrow bottoms (Stoeckeler and Skilling, 1959). This factor was also most important in a similar seeding on the Kawishiwi Experimental Forest. Stocking here, 69 percent at the end of the second year, was only 26 percent 5 years later.

Seed spots made in a hardwood opening (spring and fall seeding, both screened and unscreened) and under sprayed brush (fall seeding, screened and unscreened) had fair initial stocking but eventually failed, the former after 11 years, the latter after 4 years (Stoeckeler and Skilling, 1959).

Of two broadcast seedings, one was spring-sown with less than ½ pound of seed per acre on disked sod in a very light hardwood stand on the Nicolet National Forest; the other was snow-seeded in November with 2 pounds per acre on a disking under poor-quality hardwoods (70 square feet of basal area) on the Chippewa National Forest. The spring sowing had a fair initial stand (1,130 seedlings per acre) but was down to only 50 per acre by the second fall (Stoeckeler and Skilling, 1959). Results of the snow seeding were considerably better, 1,760 seedlings at the end of the first season and 875 seedlings with 40 percent stocking at the end of the seventh year. And on small plots here where the ground cover had been sprayed, the stand after 7 years averaged 1,750 seedlings per acre with a stocking of 55 percent.

The best results of all the balsam fir seeding trials known were obtained on screened spots that had been fall-sown on a swamp margin site — 90 percent stocking and a tree percent of 11 after 10 years. High early stocking also occurred in another seeding on sphagnum moss in a swamp, but after the fourth year all the trees died from moss smothering or from drowning (Stoeckeler and Skilling, 1959).

In a special seedbed study, LeBarron (1945) found mineral soil much superior to duff and to slash-covered duff as a seedbed for balsam fir. Survival 5 years later, however, was much better under a medium cover of trees than in the open.

AERIAL SEEDING

As far as is known, only one direct seeding of conifers has been attempted from the air in the Lake States and adjoining Canada. This was made with pelleted seed by the Ontario Department of Lands and Forests and was a failure (Rudolf, 1949). In eastern Canada, Thomson (1949) reports a 3,000-acre aerial job in New Brunswick in the winter of 1947-48. Part was on an area burned in 1947, the rest on one burned in 1944. About 3,400 pounds of seed were used, including red pine, white pine, balsam fir, white spruce, red spruce, Norway spruce, and northern white-cedar. At the end of the first year, the 1947 burn showed 50 percent stocking and up to 13,000 seedlings per acre; the older burn was much poorer. Apparently no later results have been published.

In southeastern Maine, a 320-acre portion of a fall 1947 burn was also seeded from the air in

early March 1948 just prior to a snowstorm. White pine was used at the rate of 5,000 seeds per acre. Counts made 4 years later showed that the seeding had been unsuccessful, possibly because of the severe drought during the first year (Hart, 1954). About 1,900 acres of other burns in New England were also seeded to white pine from the air during February and March of the same year, using 4,000 to 56,000 seeds per acre. Counts the first fall showed up to 2,475 seedlings per acre, but subsequent results do not seem to be available (Westveld, 1949).

While results of aerial seeding have not shown much promise in the Northeast and in eastern Canada, outstanding success with this technique is being obtained in the South. It has been used there on a large scale for the past 6 or 7 years (Derr and Mann, 1959; Mann and Derr, 1961). It need hardly be stressed, however, that seed sown from the air is subject to all of the factors causing loss as seed broadcast from the ground. Successful ground-seeding techniques must, therefore, be worked out before the operation can be taken to the air. This, of course, was the approach used in the South and is the only sound way to attack the problem.

SEED REPELLENT TREATMENTS

A few years ago much interest was aroused by the possibilities of sowing coniferous and other seeds embedded in pellets composed of various more or less inert materials that would disintegrate under favorable moisture conditions. The objectives were to provide (1) better control of seed distribution, and (2) favorable conditions for germination through the incorporation of rodenticides, insecticides, and fungicides in the material used to make up the pellet (Rudolf, 1949).

Trials have been made with pelleted seeds of Lake States conifers by various agencies including Michigan State University, Consolidated Water Power and Paper Company of Wisconsin, Ontario Department of Lands and Forests, the U.S. Fish and Wildlife Service, and the Lake States Station. The pellets have been hand-sown both in the field and in the nursery, and they have also been broadcast from aircraft. Tested were the three native pines, the two spruces, and balsam fir (Rudolf, 1949, 1950). In only one case, a test of black spruce in the field, did the pelleted seed show better results than bare seed. In one other trial, jack pine seed embedded in one type of pellet gave about as good germination as unpelleted seed when sown in the nursery at ¼-inch depth. On the other hand, seed in another type of pellet gave poorer results.

Because of these poor results and the considerable additional weight involved,[5] pelleting of conifer or other seeds has never been used to any extent for direct seeding, at least in the Lake States. Instead, interest in repellents for rodent control has shifted to the use of the light coatings of rodent-toxic and bird-repelling materials which have been so practicable and effective in direct seeding of conifers in the South. Such coatings are cheap, relatively simple to apply, and add only 25 to 35 percent to the weight of the seed. It, therefore, seems doubtful that seed pelleting will ever have much application under Lake States conditions. However, if materials are developed that appear to have merit for this purpose, the method should receive additional study.

GENERAL CONCLUSIONS

Everything considered, the various trials made since 1937 make direct seeding appear somewhat more promising than it did in Shirley's report (1937). Excluding the work of Beaufait (1960) and LeBarron (1944, 1945), 126 trials and tests of direct seeding have been made or reported on upland sites in the Lake States and adjacent Canada since 1936. In addition, six tests were made on lowland soils. Of the 132 tests, about 40 percent have turned out well, 12 percent fair, and the remainder have been poor or failures.

[5] *Pelleted jack pine seed has been found to be 9 to 25 times heavier than bare seed (Rudolf, 1950).*

On four-fifths of the good jobs, jack pine was used. Success was also obtained in three trials each of white spruce, black spruce, and balsam fir and one each of red pine and white pine.

Of the 38 jack pine trials with good results, 26 were put in disked areas by broadcast seeding or seed spotting and 7 more by one or the other of these types of seeding on burns. Several of the broadcast seedings have produced overdense stands because of the use of too much seed; the cost was likely much in excess of that of planting.

Broadcast sowing of large amounts of seed on a disking also resulted in the three successful white spruce seedings and, on an upland burn, in two good black spruce seedings. And a disked seedbed was largely responsible for two balsam fir seedings with good results.

The remaining successful jobs were seeded with the following species and methods:

Jack pine — two spot seedings on otherwise unprepared sites, 1 drill seeding in furrows, 1 with cone scattering on disked ground, and seeded on a burn with the Efco rake.

Red pine — 1 seed spotting in a fresh burn.

White pine — 1 seed spotting in a fresh burn.

Black spruce — 1 seed spotting on sphagnum moss.

Balsam fir — 1 seed spotting on mineral soil on a swamp margin.

All told, 86 percent of all successful seedings were either broadcast- or spot-seeded on disked areas or on fresh burns; whereas only 66 percent of the trials were of these types. The great importance of some kind of site preparation is also emphasized by the fact that 46 and 49 percent respectively of the seedings on burns and on disked areas were successful compared to only 13 percent of those on unprepared ground.

There were naturally failures even where the site was well prepared for seeding. Seeding on the snow in late winter showed up poorly except for one area with jack pine and one trial in black spruce where 11 pounds of seed were used per acre. The reason for the usual failure of late snow seeding is not known, but it may be due to the freezing at night of seed which has absorbed considerable moisture from the wet surface of the snow during the often warm days.

The one job with the Baker Tool, a comprehensive test of jack pine and red pine, also turned out poorly. For unknown reasons initial germination was poor.

Most of the drill seeding in furrows also failed. Seedings by this method, which Shirley (1937) considered the most dependable of those he appraised, usually showed a good initial catch. But the seedlings were either buried by washing in heavy rains or smothered over winter by leaf litter drifting into the furrows. And the surviving seedlings often became overtopped by vegetation growing on the sides of the furrows.

Competition also was the main source of seedling loss in seeding trials on disked sod and was apparently of great importance in reducing stocking on many others, especially those rated fair or poor in stocking. Seedlings from seedings are even more vulnerable to competition than planted trees. This fact apparently was overlooked, and release operations were invariably neglected (fig. 6).

Probably the most important reason for poor initial stocking of seedlings was the loss of seed to rodents and perhaps birds. On few areas was any attempt made to protect the seed. Where screened and unscreened seedings were used in parallel, the difference in favor of screening was typically large. Coating the seed with red lead also gave some rodent and bird protection.

Unfavorable weather conditions, so far as is known, were responsible for poor results on only two of the seedings made or reported since 1937. Heavy losses were caused by drought in a furrow seeding in Wisconsin in 1937, and in a broadcast seeding in the Plouff Creek burn in 1948. Elsewhere, such losses seem to have been negligible.

Where comparisons were made of spring versus fall seeding, spring usually gave better results for nondormant seed such as jack pine and red pine. Fall seeding, on the other hand, was better for the dormant seeds, white pine and white spruce.

Pretreatment such as stratification or water soaking appeared to cause somewhat earlier germination of nondormant seeds such as red pine, but the advantage soon disappeared. Perhaps in a season with critical moisture conditions in midsummer, the earlier germination would have been of benefit.

Covering the seeds with soil gave erratic results, sometimes favorable, other times unfavorable.

Summing up, the various trials of direct seeding made in the Lake States and adjacent Canada during the past 40 years have two major indications. First, direct seeding, although uneconomic in several trials, has had better results than is commonly believed. Second, most of this past work has been so haphazard, of such poor design, and so poorly carried through that direct seeding cannot be put into practice with any assurance that the good results sometimes obtained can be duplicated. Greatly needed, therefore, are well-planned comprehensive seeding studies that will evaluate all of the important factors leading to success or failure. Not until such studies are made will it be known when, where, and how direct seeding can be used reliably as a substitute for forest planting in the Lake States.

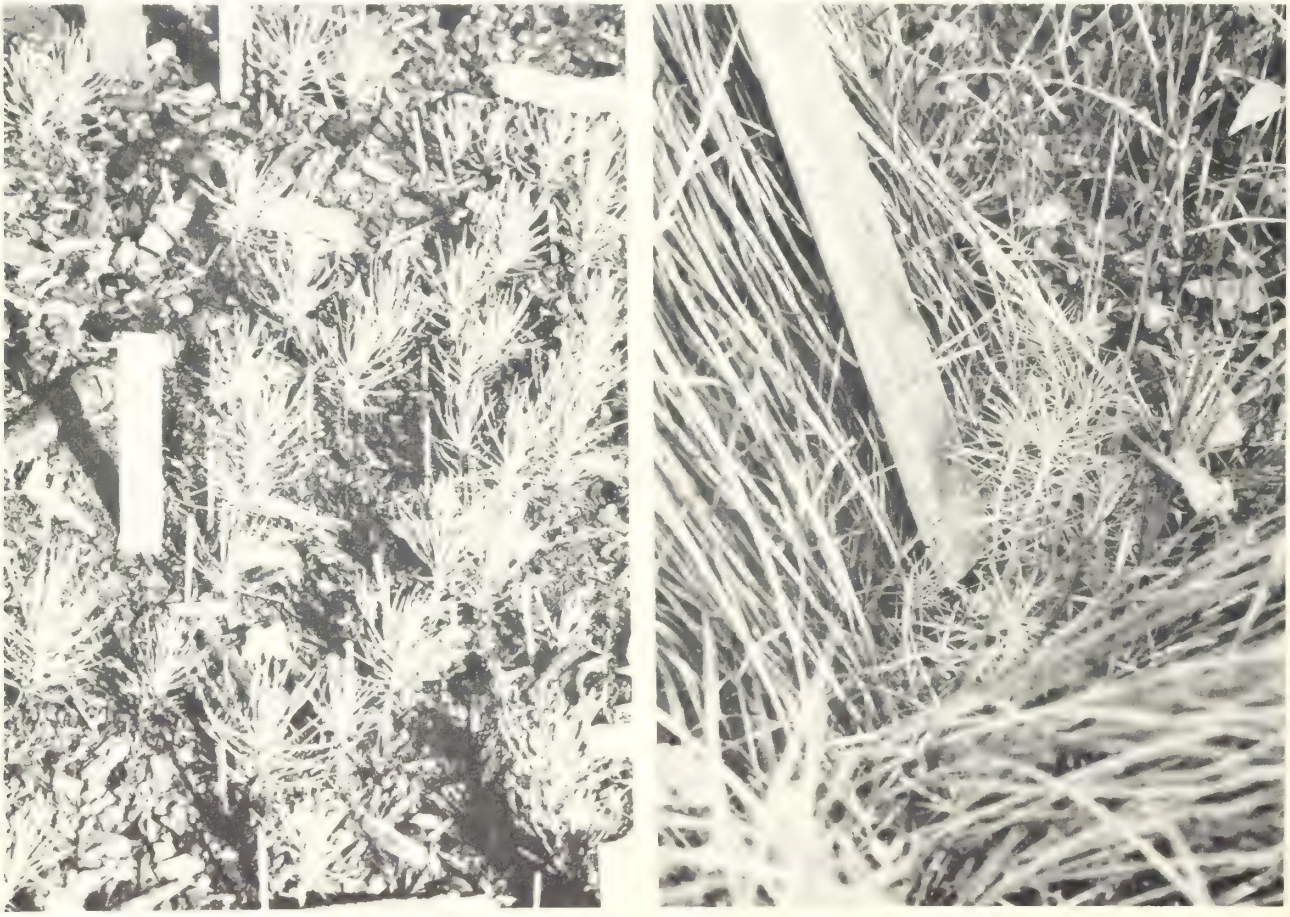

FIGURE 6. — Competing vegetation was the most serous cause of mortality in the seedings. Compare the thrifty vigorous 1-year-old jack pine seedlings on the weed-free area at the left with the spindly ones growing under grass on the right. (F-354515, 354519)

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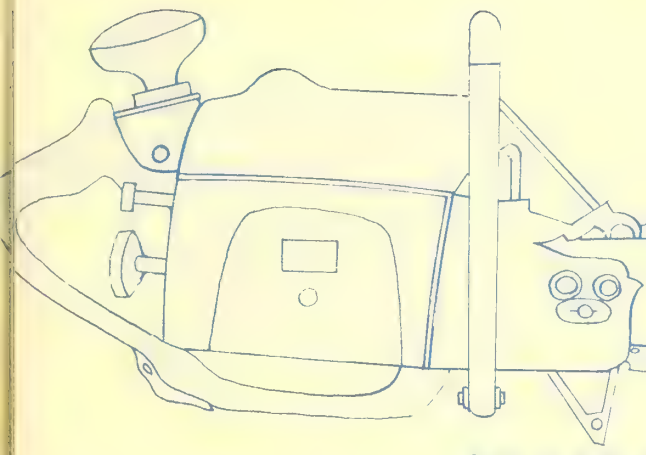

CUTTING METHODS in MIXED CONIFER SWAMPS, Upper Michigan

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CONTENTS

Page

INTRODUCTION 1

THE MIXED CONIFER SWAMP TYPE 1

- Definition 1
- Species Characteristics 2
- Ecological Succession 3
- Areas Occupied 3
- Stand Conditions 4

THE STUDY AREAS 4

CUTTING METHODS 7

- Uneven-aged Systems 7
- Even-aged Systems 8

REGENERATION 9

- Advance Reproduction 9
- Regeneration 5 Years After Cutting 10

ENVIRONMENT FOR SEEDLING GROWTH 12

- Physical Factors 12
- Biological Factors 15

GROWTH OF RESIDUAL STANDS 17

- Classification of Residual Trees 17
- Growth 17
- Mortality 17

RECOMMENDATIONS 20

SUMMARY 21

LITERATURE CITED 23

ACKNOWLEDGMENT

This report is based on the 5-year results of a cutting methods study in mixed conifer swamps. Tests were installed at several locations in the Upper Peninsula of Michigan. Agencies and private industries cooperating with the Lake States Forest Experiment Station on the installation and collection of data were American Can Company, Marathon Division; Kimberly-Clark Corporation; Mead Corporation, Escanaba Division; Michigan Department of Conservation, Escanaba River State Forest; and the Hiawatha National Forest.

FOR YOUR REFERENCE FILE

Four abstract cards are included at the back of the report for the reader's convenience.

Cutting Methods in Mixed Conifer Swamps, Upper Michigan

By John W. Benzie

INTRODUCTION

Mixed conifer swamp forests produce an assortment of wood products, provide a habitat for many species of wildlife, and furnish a storage basin for ground water. They occupy many of the poorly drained sites in the northern hardwood region. Stands vary from small patches of a few acres to several hundred acres and are made up of several species, any of which may be predominant on a given site.

Management of the mixed conifer swamp type for the production of wood, game, and water is concerned with (1) influencing the amount and kind of regeneration established after harvesting mature trees, (2) reforesting denuded swamps, and (3) increasing the growth and yield of young stands. One of the most important problems is securing prompt and adequate regeneration of the conifer species (Thornton, 1957a).

A survey of reproduction on cutover swamplands in the Upper Peninsula of Michigan was made in 1951 (Zasada, 1952). It showed that new forest stands were usually established after commercial logging. However, the proportion of coniferous reproduction was less than in the original stands, and severe competition from shrub and hardwood species sometimes delayed the development of coniferous reproduction for many years. These results indicated the need for further testing of even-aged and uneven-aged cutting methods to obtain conifer regeneration.

Two detailed studies and three less intensive ones were installed between 1952 and 1955. The first 5-year results from these studies are the basis for this report.

THE MIXED CONIFER SWAMP TYPE

Definition

The mixed conifer swamp type is composed of northern white-cedar (*Thuja occidentalis*), black spruce (*Picea mariana*), white spruce (*Picea glauca*), balsam fir(*Abies balsamea*), and a wide variety of minor species. The proportion of tamarack (*Larix laricina*) has been reduced by heavy infestations of the larch sawfly (*Pristiphora erichsonii*) in many stands where it might otherwise be a significant component. Other associated species may include red maple (*Acer rubrum*), black ash (*Fraxinus nigra*), yellow birch (*Betula alleghaniensis*), paper birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), bigtooth aspen (*Populus grandidentata*), and balsam poplar (*Populus balsamifera*). Species that occur less frequently are American elm (*Ulmus americana*), eastern hemlock (*Tsuga canadensis*), sugar maple (*Acer saccharum*), and eastern white pine (*Pinus strobus*).

This complex of species is recognized in "Forest Cover Types of North America" (Society of American Foresters, 1954) as transition forms or variants of the three conifer swamp types; black spruce (no. 12), tamarack (no. 37), and northern white-cedar (no. 38). Since these transition forms are composed of the same species, they are usually considered to be one mixed conifer swamp type in the Lake States. The division between the mixed

NOTE: the author is Research Forester (Forest Management) at the Lake States Forest Experiment Station. The research was done at the Station's Northern Hardwoods Project, Marquette, Mich.

conifer swamp type and one of the pure types is defined as the point when that species predominates (amounts to 50 percent or more of the volume), but this separation is generally not made in practice as long as the other species are well represented in the stand.

Although some stands have nearly equal stocking of cedar, spruce, and balsam, most have a greater proportion of one species. Quite often a stand has relatively high proportions of two species such as cedar and spruce, or spruce and balsam. Almost any combination can be found in the mixed conifer swamp type.

In addition to the variations in proportion of the major species the associated species vary in the different mixed conifer swamps. These species, which are mostly hardwoods, fall in two general groups: (1) red maple, black ash, and yellow birch; and (2) aspen, balsam poplar, and paper birch. The hardwoods associated with the conifers are often the species found in the surrounding forest type. Mixed conifer swamps surrounded by northern hardwoods are most apt to have red maple, black ash, and yellow birch as associated hardwoods; those with an aspen-paper birch type around them will more likely have that species group in mixture. These mixtures are not limited to a transition zone between the surrounding type and the mixed conifer swamp type. They usually occur throughout the entire swamp stand.

Species Characteristics

The silvical habits of the species growing together in the mixed conifer swamps vary considerably. Both long-lived and short-lived, tolerant and intolerant, and fast- and slow-growing species occur. Although all of the major species produce seed in the fall, some of the associated species produce seed in the spring. Some species also regenerate by layers and others by sprouts and suckers. A brief summary of the silvical characteristics of the major species will help to explain their response to various treatments and to evaluate their role in the stand.

Northern white-cedar. — This is a shallow-rooted, slow-growing, small to medium-sized tree, commonly 40 to 60 feet in height at maturity (Godman, 1958). In general, it does best in near-neutral or only slightly acidic swamps with a shallow organic layer of well-decomposed woody peat or muck and moving ground water. It is a tolerant, long-lived tree that reaches ages of 400 years or more. Advanced reproduction of both seedlings and layers is usually present but cannot develop under dense, even-aged swamp stands. In old-growth stands with small openings caused by natural mortality, cedar regeneration must compete with the more tolerant balsam fir and associated hardwood species.

Balsam fir. — This small to medium-sized tree is commonly 40 to 60 feet in height when mature. It is very tolerant and a prolific seed producer (Hart, 1959). Seedling growth is usually slow, but older trees grow quite rapidly under favorable conditions (Roe, 1950). It is a shallow-rooted tree that grows on a wide variety of moist to wet sites. Because balsam fir is a short-lived tree, seldom reaching 100 years of age, it is often less common in the overstory of old, fully-stocked stands than in young ones. However, when small openings are created in old stands balsam fir is likely to increase along with the hardwoods, because of the abundance of tolerant seedlings generally present.

Black spruce. — This is a medium-sized tree, commonly about 60 feet in height at maturity. It is intermediate in longevity between northern white-cedar and balsam fir, reaching ages up to 250 years (Heinselman, 1957). It is usually considered less tolerant than either cedar or balsam fir but more tolerant than tamarack. Although black spruce seedlings and layers will become established under a closed forest canopy, they cannot survive for more than a few years (Heinselman, 1959). In the northern hardwood region, black spruce is largely confined to organic soils ranging from sluggish bogs to seepage areas with good internal drainage. Competition from cedar, balsam fir, and white spruce increases on the better drained sites. There, successional changes are more rapid and black spruce is eventually forced out.

White spruce. — Although this tree makes its best growth on well-drained loams, it is common in many of the mixed conifer swamps where it reaches 80 to 100 feet in height and over 20 inches in diameter at breast height. It is similar to black spruce in both tolerance and longevity. White spruce starts growth 2 weeks earlier in the spring than black spruce and is therefore more susceptible to frost injury. It is also more exacting in its nutrient requirements than is either black spruce or balsam fir (Nienstaedt, 1957).

Tamarack. — This is a moderately long-lived and very intolerant tree. It is relatively fast growing and occurs as a dominant tree in the overstory of some mixed conifer swamps, but it is practically never found in the understory. When tamarack is able to survive both competition and the larch sawfly, it attains an average size of 60 to 80 feet in height and 14 to 20 inches d.b.h. (Roe, 1957).

Hardwood tree species. — These, when associated with the mixed conifer swamp type, are often defective and poor in quality. They usually comprise a minor portion of the overstory but reproduce vigorously. The aspen-balsam poplar-paper birch group is intolerant, and the red maple-black ash-yellow birch mixture is more tolerant. The two groups generally occur in separate stands, but occasionally they grow together. American elm and sugar maple are also common in some stands. Spring and fall seeders are represented in both groups. The seed of red maple, American elm, quaking aspen, bigtooth aspen, and balsam poplar ripens in the spring, whereas the seed of black ash, sugar maple, yellow birch, and paper birch ripens in the fall. In addition, all of the species except yellow birch are prolific sprouters. The aspens and balsam poplar also regenerate by root suckers. Juvenile height growth of nearly all the hardwood species greatly exceeds that of the conifers, but the swamp sites apparently favor the conifers as the species mature. Advance reproduction of the more tolerant hardwood species is usually present, but the intolerant species do not regenerate unless there is an opening in the overstory.

Nonmerchantable shrub and tree species. — These most frequently include mountain maple (*Acer spicatum*), speckled alder (*Alnus rugosa*), dogwood (*Cornus spp.*), honeysuckle (*Lonicera* spp.), and ribes (*Ribes spp.*).

Ecological Succession

Many of the present mixed conifer swamp stands developed after the widespread tamarack mortality caused by the larch sawfly infestation from 1890 to 1910. Later some of the swamps were cut over for single products such as cedar poles or spruce pulpwood. Other disturbances, such as fire and windthrow, have also altered the succession.

One ecological classification of cover types for northern Michigan includes mixed conifer swamps in Stage Eight of a series of ten stages originating from seepage bogs or marshes (Graham, 1945). The previous stage (Seven) is characterized by highbush cranberry, dogwood, and alder. The next advanced stage (Nine) has red maple, yellow birch, American elm, and white pine. A more detailed discussion of successional changes within this stage is provided by a recent description of the lowland forests in northern Wisconsin (Christensen et al., 1959).

Tamarack is said to be the first tree species to invade the ericaceous shrub stage of the open bog. It is followed by black spruce. These two species may remain a long time in various proportions, but eventually they are replaced by a mixed stand dominated by northern white-cedar and often including balsam fir and black ash. The final stages of succession for these forests are most likely hardwoods with mixtures of eastern hemlock.

Areas Occupied

In the northern Lake States, 2,356,000 acres have been classified as conifer swamp (Cunningham et al., 1958; Findell et al., 1960; Stone and Thorne, 1961). This includes the cedar, black spruce, and tamarack swamps of Michigan and Wisconsin, but only the cedar swamps in Minnesota. The black spruce and tamarack swamps in Minnesota are generally pure types and more typical of the boreal forest region. Although some of the swamps included in the northern hardwood region are pure cedar, black spruce, or tamarack, most of them have a mixture of the conifer species.

The mixed conifer swamp type is found in the wet depressions and drainageways scattered throughout the northern hardwood region. Locally, it may cover only a few acres or several hundred. A large proportion of the individual swamps are less than 100 acres in size, forming pockets or depressions only a few feet lower in elevation than the surrounding topography. Often a ridge or an impervious layer forms the swamp boundary, separating it from the gently rolling or sloping lands that may be at a lower elevation but are better drained.

Soils supporting the mixed conifer swamp type have been grouped in three general classes: (1) peat, (2) muck,[1] and (3) wet or poorly drained

[1] *In this general classification, muck is defined as a well-decomposed organic soil.*

mineral soils (Zasada, 1952). Usually black spruce is the predominant species on the peat soils, and northern white-cedar occupies the muck soils with varying mixtures of the other species. The wet or poorly drained mineral soils often have a more complex mixture, including northern white-cedar, balsam fir, black spruce, white spruce, and several hardwood species.

Stand Conditions

Both single-story and multiple-story stands occur. Single-story stands have a closed canopy and may be composed of one or more age classes. Multiple-story stands usually do not have a closed canopy and always have two or more age classes. Multiple-story stands generally have lower stocking than single-story stands.

Past treatment and site are the two main factors affecting stand condition. A fully stocked stand of regeneration originating after a disturbance that eliminates the entire overstory will form a single-story even-aged stand. On less favorable sites where the regeneration is not adequate for full stocking, multiple-story, uneven-aged stands result. New stands following disturbances that do not completely remove the overstory start out as multiple-story stands, but on the better sites they will develop into single-story stands with a closed canopy consisting of two or more age classes.

Past treatments include not only logging but also disturbances by fire, wind, insects, disease, and animals. These, acting alone or in various combinations, have affected the present stand conditions. One of the most notable effects is the alteration in composition caused by severely reducing or eliminating one or more species. Commercial clearcutting has often removed only one or two species, leaving those for which no market existed at the time. Insects or diseases specific to one species, such as the larch sawfly, also change species composition. Some factors, such as fire and sometimes wind or logging, affect all species in a given area. The influence of these factors on stand condition may be modified by site.

Site indices have been prepared for the major species found in the mixed conifer swamp type (Gevorkiantz, 1956, 1957a, b, c, d) and are at present the best available measure of productivity. However, more information is needed on site quality, especially the identity and influence of factors affecting successional changes, before site character can be used to full advantage in mixed conifer swamp management.

THE STUDY AREAS

The mixed coniferous swamps used in this cutting experiment are located at Amasa, Dukes, Newberry, and Norway, Mich. (fig. 1). Two separate swamps on the Upper Peninsula Experimental Forest at Dukes were used for detailed measurements and observations. Less intensive measurements were taken at three other experimental areas to provide supporting data for the test.

FIGURE 1. — Mixed coniferous swamp study areas in the Upper Peninsula of Michigan.

There was considerable variation among these study areas typical of that found in the mixed conifer swamp type. The stand at Amasa had a relatively light overstory density averaging only 77 square feet of basal area per acre (table 1). Its multiple-story structure was characteristic of uneven-aged stands. Ages of northern white-cedar exceeded 200 years, spruce ranged up to 100 years, and balsam fir 80 years. All of the other stands were single story with a closed canopy. The two at Dukes had several age classes ranging from 30 to 120 years, but 75 per cent of the trees were in the 60- and 90-year age classes (fig. 2). The stands at Newberry and Norway were primarily one age class originating after a commercial clearcutting 60 years ago.

Only the two study areas at Dukes had more than half of the trees in one species, which was northern white-cedar. Spruce and balsam fir, however, were well represented and together accounted for about one-third of the trees. At Norway, northern white-cedar also comprised the largest

proportion of the stand but was less than half of the trees. At Newberry spruce was the largest component of the stand with 46 percent of the trees, followed by cedar with 38 percent. At Amasa the species were more evenly divided, with 36 percent spruce, 29 percent balsam fir, and 28 percent cedar. Tamarack accounted for 8 percent of the trees at Norway but occurred only as scattered trees in the other stands. An occasional white pine or hemlock was also found on the study areas.

The associated hardwoods, ranging from 5 to 22 percent of the trees, also varied by species composition among the study areas. Red maple and black ash were the most abundant hardwoods in the two study areas at Dukes, with some American elm, yellow birch, and sugar maple occurring throughout the stands. Paper birch was the most numerous at Amasa, with red maple and yellow birch also quite common. The stands at Newberry and Norway had primarily aspen, balsam poplar, and paper birch, with only scattered trees of red maple and black ash.

This variation in species composition and the differences in stand structure among the study areas provide a good representation of the mixed conifer swamp type (fig. 3). Although stand characteristics varied considerably there was apparently less difference between the sites.

TABLE 1. — *Mixed conifer swamp overstory on five study areas; trees 5.6 inches d.b.h. and larger*

Study area	Average d.b.h.	Stand density per acre		Overstory composition based on number of trees per acre			
		Basal area	Trees	Spruce	Balsam fir	Cedar	Hardwood
	Inches	*Sq. ft.*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*
Amasa	7.1	77	277	36	29	28	7
Dukes-A	8.9	219	507	11	16	62	11
Dukes-B	8.8	188	448	25	11	59	5
Newberry	5.8	175	936	46	7	38	9
Norway[1]	6.0	109	554	20	6	44	22

[1] *Besides the species listed here, an additional 8 percent of the trees were tamarack.*

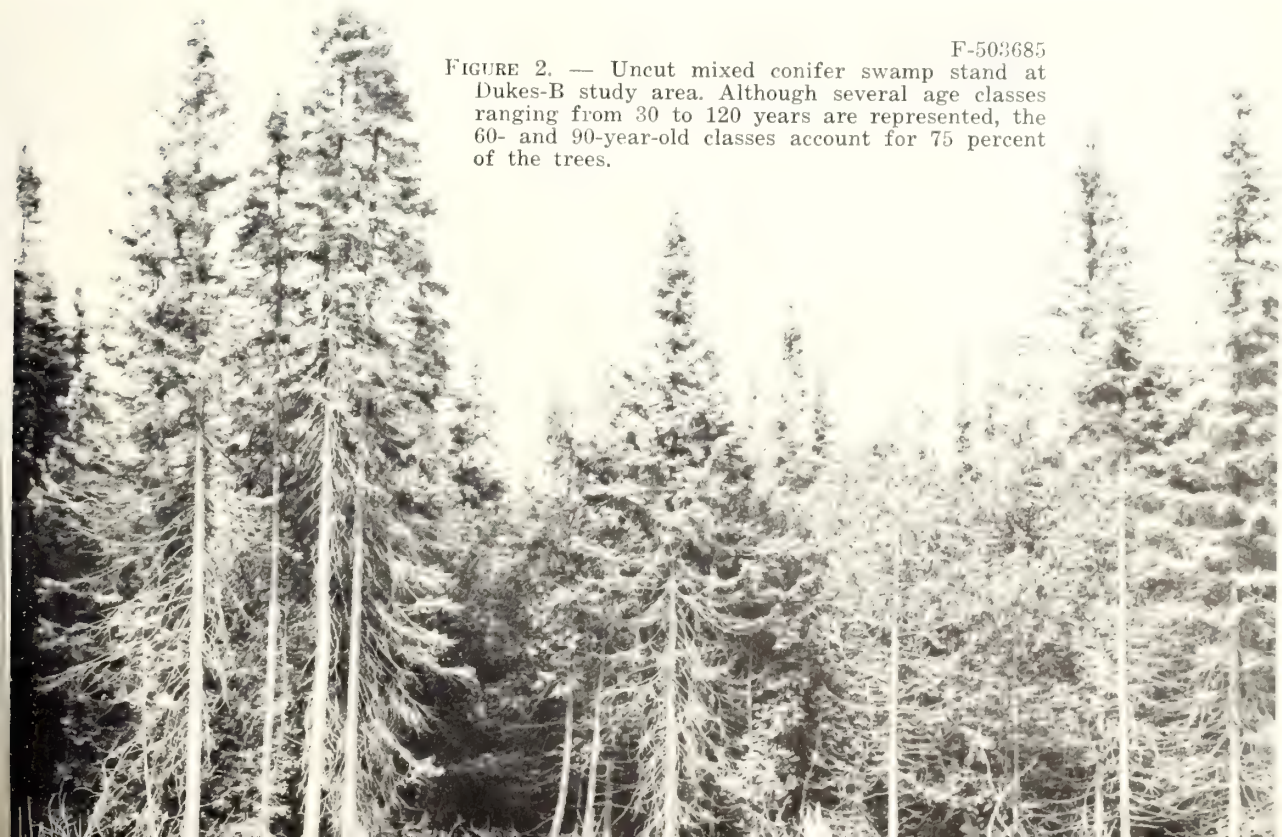

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FIGURE 2. — Uncut mixed conifer swamp stand at Dukes-B study area. Although several age classes ranging from 30 to 120 years are represented, the 60- and 90-year-old classes account for 75 percent of the trees.

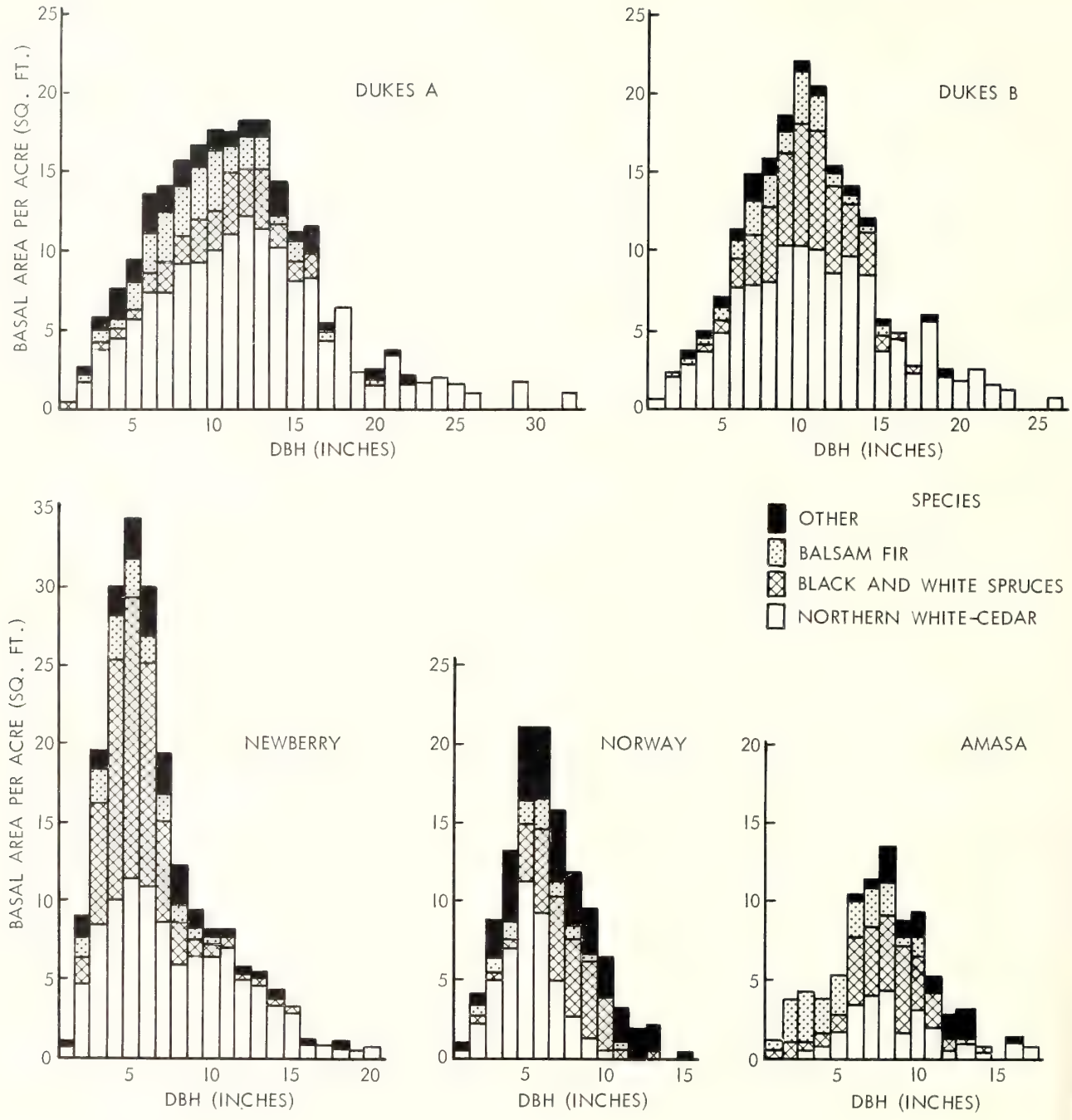

FIGURE 3. — Stand structure and composition at the five study areas. D.b.h. is diameter at breast height.

Site indices were obtained for black spruce, balsam fir, and northern white-cedar at all study areas except Amasa where they could not be determined because of the uneven-aged stand condition. Site indices, expressed as total height at 50 years, were 40 feet for black spruce, 45 feet for balsam fir, and 30 feet for northern white-cedar on the two study areas at Dukes. On the study areas at Newberry they were 40, 40, and 25 feet and at Norway 45, 50, and 30 feet respectively. Water movement was moderate through each of the study areas.

The soil on the two detail study areas at Dukes was classified as Lupton muck. It averaged 3.5 feet deep in study area A and 3.1 feet deep in area B but ranged from 2 to 6 feet in both areas. Reaction of the surface layers was near neutral, with an average pH of 7.5, but below 1 foot it was more alkaline, with a pH of 8.0.

The size of the study areas ranged from 10 to 30 acres. The minimum was 5 acres for each cutting method in the detail studies at Dukes and 2 acres in all other study areas.

CUTTING METHODS

Five cutting methods were tested. Tree selection and designation by diameter limits were used for the all-aged systems. The even-aged systems were a two-cut shelterwood, clearcut strips, and clearcut blocks.

All five methods were included in the studies at the Upper Peninsula Experimental Forest and at Newberry. Clearcutting in blocks was not tested in the studies at Amasa and Norway.

TABLE 2. — *Basal area of residual stands; all trees 5 inches d.b.h. and larger*
(In square feet per acre)

Study area	Cutting method			
	Uncut	Selection	Diameter limit	Shelterwood
Amasa	77	48	60	44
Dukes-A	219	112	38	60
Dukes-B	188	119	106	54
Newberry	175	94	94	89
Norway	109	88	76	49

Uneven-aged Systems

Selection Cutting

Individual tree selection removed between one-fourth and one-half of the basal area by cutting the poor-risk and poor-quality trees in all size classes over 4 inches d.b.h. The residual stands were composed of spruce, cedar, and balsam fir in approximately the same proportions as found prior to cutting. Only a few trees of other species were left scattered throughout the stands. The cutting cycle was undetermined but was expected to vary between 10 and 20 years depending upon the development of regeneration and growth of the residual stands.

The cutting provided small openings and left a relatively uniform spacing in the overstory. The residual overstory ranged from 48 to 119 square feet of basal area per acre, but most of the variation was due to the variation in original stocking (table 2).

Diameter-limit Cutting

The objective of the diameter-limit cutting was similar to that of the selection cut. A diameter limit was set for spruce, cedar, and balsam fir to insure that the residual stand would have about the same proportion of these species as the original stand. All trees above these limits and the merchantable trees of all other species were designated for cutting. Diameter limits used on the five study areas ranged from 6 to 12 inches d.b.h. for spruce, 6 to 10 for cedar, and 6 to 8 for balsam fir.

Except for the study identified as "Dukes-*A*", the diameter-limit cutting left approximately the same average stand density as the selection cutting (table 2). The residual stand density at Dukes *A* was considerably lower than planned because of a severe ice storm during logging. Since the storm occurred at the time of logging, most of the trees were utilized and included in the cut, leaving the residual stand density at 38 square feet of basal area per acre.

In all of the diameter-limit cuttings the residual stand provided less uniform cover than the original stand. This cutting method emphasized lack of uniformity in the original stand instead of minimizing it as the selection cut did. Portions of the stand with lower densities had more trees over the diameter limit than did areas with higher densities; consequently the most open parts of the stand were cut the heaviest.

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FIGURE 4. — Residual shelterwood stand of cedar, black spruce, white spruce, and balsam fir 2 years after cutting.

Even-aged Systems

Two types of even-aged silviculture were tested. One involved complete removal of the overstory on part of the area, either in narrow strips or small blocks. The other involved partial removal of the overstory over the entire area, leaving the most vigorous and best developed trees as a shelterwood stand for seed production and site protection. Both types presuppose subsequent cuts to remove the shelterwood overstory and the adjacent strips and blocks.

Shelterwood Cutting

In the shelterwood method, spruce, balsam fir, and cedar trees were selected to provide a uniform overstory of one-fourth to one-half the original basal area (fig. 4). The trees in the residual shelterwood stand were selected for quality, vigor, and species. Quality was determined by cull and form. Tree vigor was based on crown class and competition with neighboring trees. The best quality and most vigorous spruce, cedar, and balsam fir in that order of preference were left uniformly spaced over the area. Species composition in terms of basal area averaged 44 percent spruce, 44 percent cedar, 10 percent balsam fir and 2 percent other species in the two study areas at the Upper Peninsula Experimental Forest. On the other study areas, spruce ranged from 10 to 31 percent, cedar from 9 to 73 percent, and balsam fir from 2 to 7 percent of the total basal area.

Clearcutting in Strips and Blocks

Clearcutting methods were included in all of the studies, but only those at Dukes removed the entire overstory (fig. 5). The others were "merchantable" clearcuts and left an overstory of unmerchantable trees ranging from 35 to 65 square feet of basal area per acre. The differences between the merchantable clearcuts and the silvicultural clearcuts, which removed the overstory completely, were so great that they cannot be considered the same treatment. Evaluation of the clearcutting methods is therefore based on the results obtained from the silvicultural clearcuttings in the two stands at Dukes.

Both the strip and block clearcutting methods removed the entire overstory on one-third of the treatment area. Strips were 75 feet wide and oriented in an east-west direction. Blocks were 2 chains square or 0.4 acre in size.

F-471974

FIGURE 5. — The clearcutting methods in the two studies at Dukes removed the entire overstory in 75-foot-wide strips and 2-chain-square blocks.

REGENERATION

Advance Reproduction

The five study areas were each fully stocked with regeneration before cutting if all sizes and all tree species are included. Advance reproduction was present on 96 to 100 percent of the milacre plots. Reproduction less than 6 inches tall was abundant on all areas, but most of it was only 1- or 2-year-old seedlings. They are being continually replaced by new regeneration and can be considered as universally present in mature mixed conifer swamps.

The study areas at Norway and Amasa had regeneration 6 or more inches tall on 65 and 75 percent of the plots respectively. At Newberry, however, only 4 percent of the plots had reproduction this tall. The two detail study areas at Dukes averaged 80 percent stocking with advance reproduction of this size.

Species composition of the advance reproduction 6 or more inches tall was quite variable among the study areas. At Dukes the conifers accounted for only about one-third of the regeneration but on the other study areas they were between 50 and 80 percent of the total, with balsam fir predominant. Spruce had the least stocking in all stands except at Amasa, where hardwoods had the least.

Reduction in stocking by the mechanical effects of logging were kept to a minimum by the protective cover of snow during the winter operations (Thornton, 1957b). Losses of advance regeneration were primarily due to exposure and the accumulation of slash. Both the total area covered with slash and the area covered with deep slash increased with the intensity of the cut (table 3).

The exposure, of course, also increased with the intensity of the cut. The decrease in stocking of advance reproduction after cutting ranged from 12 to 38 percent, being least in the partial cuttings and greatest in the clearcuttings.

Release of advance reproduction was also related to the intensity of the cut. Before cutting, the reproduction on 12 percent of the milacre plots was classified as "free to grow".[2] After cutting, the plots stocked with reproduction free to grow had increased for each of the methods. The increase ranged from 8 percent in the selection cutting method to 23 percent in the clearcut strips.

The total stocking of advance reproduction after cutting ranged from 38 to 56 percent. Reproduction free to grow ranged from 26 to 47 percent. In general, the total stocking decreased with the intensity of the cut, but the area stocked with reproduction free to grow increased.

[2] *Reproduction that had a reasonable chance of reaching the overtopping crop classified as "free to grow".*

TABLE 3. — *Effects of cutting methods on slash accumulation and advance reproduction in the two study areas at Dukes immediately after cutting*

Cutting method	Overstory basal area[1]		Area covered with-		Milacres of advance reproduction[2]			
	Before cutting	After cutting	Deep slash[3]	Any slash	Destroyed	Released	Free to grow	Total
	Sq. ft.	*Sq. ft.*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Uncut	189	189	0	0	0	0	12	71
Selection	223	115	19	57	15	8	26	56
Diameter limit	205	70	29	75	12	15	35	48
Shelterwood	200	57	33	75	12	19	44	56
Clearcut strips	199	0	51	86	38	23	47	49
Clearcut blocks	200	0	49	80	29	22	37	38

[1] *All trees 5.6 inches d.b.h. and larger.*
[2] *Includes all tree species between 6 inches tall and 0.5 inch d.b.h.*
[3] *Over 3 feet high.*

Regeneration 5 Years After Cutting

Regeneration established after cutting was not observed separately from the advance reproduction surviving the first 5 years. Thus the total regeneration represents the net effect of the various cutting methods. The fifth-year results include both the decreases in advance reproduction due to logging and subsequent exposure or other causes and the increases due to new regeneration.

Because of the abundant advance reproduction before cutting, the total density of regeneration between 6 inches high and 0.5 inch d.b.h. in the cut stands was only slightly greater than the 7,085 trees per acre present in the uncut stands at Dukes (table 4). However, considering only the conifer species, the density ranged from less than 2,000 to over 5,000 stems per acre. The density of the conifer regeneration was less in the uneven-aged cutting methods (selection, 1,998; and diameter limit, 2,542) than in the even-aged methods (shelterwood, 2,897; clearcut strips, 3,844; and clearcut blocks, 5,135).

Composition of the established regeneration 5 years after cutting was closely related to the intensity of the cut. The proportion of spruce, balsam fir, and northern white-cedar reproduction was greatest where the overstory was completely removed (fig. 6). The proportion of hardwood reproduction decreased as the residual overstory density decreased. The net result was approximately the same total density in all cutting methods, but the cutting methods that were most favorable for conifers were least favorable for hardwoods. Although the density of each conifer species 5 years after cutting increased with the proportion of overstory removed, these increases were not equal. Spruce increased the most and balsam fir the least. Cedar constituted practically half of total conifer reproduction in each cutting method but

TABLE 4. — *Fifth-year regeneration 6 inches or more tall on the two study areas at Dukes*

Cutting methods	Number of stems per acre					Percentage of milacres stocked with-		
	Spruce	Balsam fir	Cedar	Hardwood	Total	Conifers	Hardwood	Any tree
Uncut	14	390	1,877	4,804	7,085	30	88	92
Selection	37	977	984	5,456	7,454	51	80	87
Diameter limit	42	1,183	1,317	5,846	8,388	61	84	88
Shelterwood	196	1,327	1,374	4,953	7,850	71	92	98
Clearcut strip	223	1,716	1,905	4,405	8,249	75	78	91
Clearcut block	467	2,092	2,576	3,509	8,644	75	75	89

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FIGURE 6. — Conifer reproduction in clearcut blocks and clearcut strips had a better opportunity to compete with shrubs and hardwood species than that in partially cut stands.
F-503688

was 82 percent of that in the uncut stand. The number of stems of cedar reproduction in the uncut stand was less than in the clearcut strips and blocks but more than in the partially cut stands.

The distribution of the reproduction must also be considered in evaluating the effect of the cutting methods. Although the actual requirement for satisfactory stocking is not known, an arbitrary minimum of 60 percent of the milacres stocked with at least one stem, which is commonly used, was established for this study. Using this standard, all cuttings except the selection method resulted in satisfactory stocking of conifers alone (table 4). The selection cutting, with only 51 percent stocking of conifers, might also be considered satisfactory since it is scheduled to receive additional selective cuts which may increase the conifer stocking. However, all of the partially cut areas (selection, diameter limit, and shelterwood) are more heavily stocked with hardwood reproduction than are the clearcut areas (figs. 7 and 8). The competition of this hardwood reproduction could

FIGURE 7. — Competition from shrubs and hardwood reproduction was the most severe in partially cut stands. The conifer regeneration in this shelterwood stand at Dukes was well established 5 years after cutting but it was overtopped with shrubs and hardwood reproduction up to 8 feet tall as shown by the 6-foot range pole.

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FIGURE 8. — Competition from shrubs and hardwood reproduction in the clearcut areas was not as severe as in the partially cut stands, but it will still delay the growth of conifers unless it is controlled.

well limit the development of established conifer reproduction and prevent the establishment of additional conifers following future cuts in these stands.

The results at Amasa, Newberry, and Norway differed from those at Dukes in some respects. Stocking of conifer regeneration 6 or more inches tall showed the same general trend for the various cutting methods in all study areas. But compared to Dukes, the percentage of milacres stocked was higher at Amasa, lower at Newberry, and approximately the same at Norway. Part of these differences is undoubtedly related to the composition of the overstory at the study areas. Amasa had the highest proportion of balsam fir, which is a very tolerant species and regenerates more abundantly than the other conifers, whereas Newberry had the highest proportion of spruce, which is the least tolerant, except for tamarack, and the most difficult to regenerate.

Competition from hardwood species was much more variable among the study areas. There was more hardwood reproduction at Dukes than at any of the other study areas, and the cutting methods did not have the same trends in all areas. Composition of the overstory hardwood species was quite different among the study areas as described earlier. This probably explains much of the variation, but the application of the cutting methods also contributed to it. Commercial clearcuttings left a residual stand of unmerchantable trees, making conditions more nearly like those in the partial cuttings than those in the silvicultural clearcuttings where the entire overstory was removed.

Considering all the information available from these study areas the general conclusions agree with the findings at Dukes. Conifer reproduction fared best in the open, where it was more abundant and had the least competition from hardwoods.

● ENVIRONMENT FOR SEEDLING GROWTH ●

The amount and kind of competing vegetation and use by animals as well as some measures of the micro-environment were recorded for each of the cutting methods on the two study areas at Dukes. These data were used to compare the treatments in terms of overhead shade, air temperature, and seedbed moisture conditions. The differences in conifer regeneration and competition were related to these factors.

Physical Factors

The effects of shade, temperature, and seedbed moisture on regeneration cannot be evaluated directly from this study, but a general description of the conditions created by the cutting methods can be obtained. Briefly, the clearcuttings had less overhead shade, lower minimum temperatures, and fewer "dry" seedbeds than did the partial cuttings. Details are discussed at some length below.

Overhead shade

Classification of the milacre seedbeds by overhead shade conditions shows that the proportion of the area shaded was related to the residual basal area as would be expected. Overhead shade was classified as none, moderate, or heavy based upon the crown cover directly over the plot and the estimated proportion of the day that sunlight would fall on the seedbed.

Conifer regeneration 6 or more inches tall was most abundant and most uniformly distributed where the overhead shade was the least (table 5). As the amount of overhead shade increased, conifer regeneration decreased. Moderate shade was most favorable for hardwoods.

TABLE 5. — *Stocking and density of regeneration between 6 inches tall and 0.5 inch d.b.h. related to overhead shade on study areas at Dukes 5 years after cutting*

Overhead shade	Conifers		Hardwoods	
	Stocking	Density	Stocking	Density
	Percent	*Number*	*Percent*	*Number*
None	70	3,100	84	4,600
Moderate	53	2,100	89	5,400
Heavy	41	2,100	79	4,400

Temperatures

Frost was observed on the ground 2 weeks earlier in the clearcut areas than in any of the cutting methods with a residual overstory. This observation prompted the recording of air temperatures in the clearcut blocks, the shelterwood, and the uncut stand during the growing season. Two years' records show that maximum temperatures under the shelterwood stand averaged 5 degrees higher than under the uncut stand, but minimum temperatures were approximately the same in both stands. In the clearcut blocks minimum temperatures averaged 6 degrees lower than in either the shelterwood cutting or the uncut stand, and maximum temperatures averaged 6 degrees higher than in the uncut stand or nearly the same as in the shelterwood cutting.

The significance of these findings is not fully understood, but perhaps the combination of both higher and lower temperatures in clearcut blocks and strips favors the swamp conifers in competition with shrub and hardwood species. High daytime temperatures early in the season stimulate bud bursting, and the succulent tissues are then subjected to frost injury from low nighttime temperatures. Phenological records at the Upper Peninsula Experimental Forest show that growth starts about May 15 for most of the competing shrub and hardwood tree species except black ash. The average date that growth starts for black ash, balsam fir, and northern white-cedar is 10 days later on May 25, and for black spruce it is not until June 6.

Moisture

Because the ground water level is usually near the surface in mixed conifer swamps, moisture is one of the most important factors affecting the vegetation. The fluctuations of the ground water levels were recorded during the growing season in an uncut portion of study area *B* at Dukes (fig. 9). Except for two short periods during August 1957 the ground water was not more than 1 foot below the average ground surface and most of the time it was less than 0.5 foot.

The combination of high water table and uneven ground surface or microtopography results in some seedbeds that are periodically under water and some that get very dry in the summer. In an attempt to establish a relationship between stand treatment and surface moisture conditions, each milacre plot was classified as "wet", "average", or "dry" based primarily on its elevation in relation to the water table. The smallest proportion of average seedbeds was on the uncut areas, and the largest proportion on the clearcut areas (table 6). A smaller proportion of the area was classified as wet in the cut stands than in the uncut stands. The proportion classified as dry was least in the clearcut areas and about the same in uncut and partially cut stands. Thus the proportion of wet seedbeds decreased with all methods of cutting, but the proportion of dry seedbeds did not decrease until the complete overstory was removed.

TABLE 6. — *Classification of milacre seedbeds by moisture condition 5 years after cutting on study areas at Dukes*

(*in percent*)

Cutting method	Moisture condition on seedbed		
	Wet	Average	Dry
Uncut	26	47	27
Selection	19	55	26
Diameter limit	16	57	27
Shelterwood	17	56	27
Clearcut strips	17	72	11
Clearcut blocks	12	71	17

These differences in seedbed moisture conditions may have been caused by changes in both the ground surface and water table. The ground surface was modified to some extent by the logging equipment even though the operations were carried out during the winter months. No direct measurements were taken, but the disturbance was observed to increase with the intensity of cutting. The cutting methods may have influenced the water table also by their effect on precipitation reaching the ground and by possible changes in evapotranspiration.

One-third of the total precipitation in the central part of the Upper Peninsula of Michigan falls as snow. There is very little snowmelt during the winter months; consequently most of this moisture

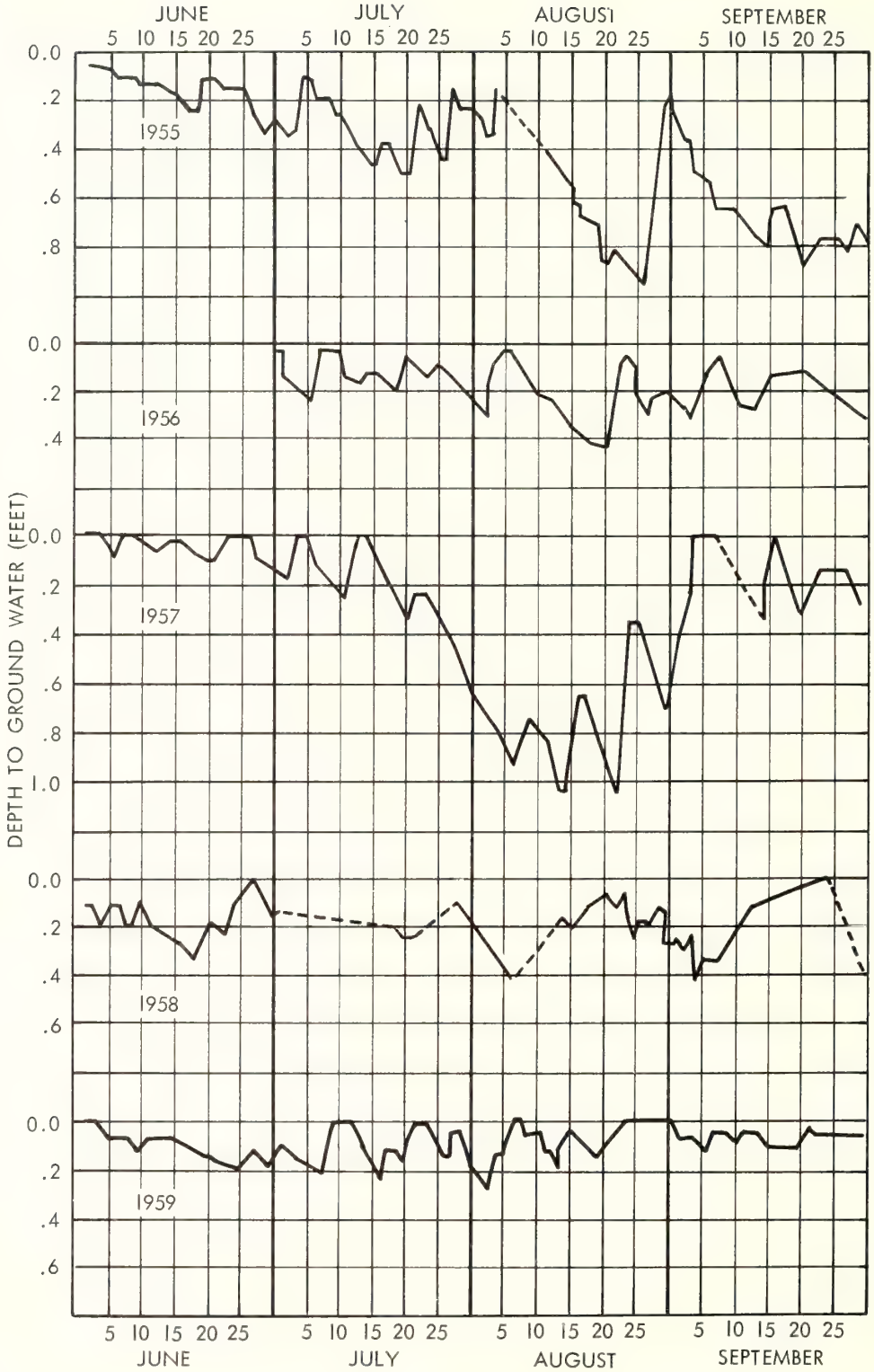

FIGURE 9. — Patterns of ground water levels in uncut mixed conifer swamp, Dukes study area *B*.

is held in the snowpack until spring break-up and becomes available just before the start of growth (fig. 10). This is an important source of soil moisture recharge.

Measurements in the study area over 4 winters showed maximum snow depths during the second or third week of March. The snowpack in the clearcut areas averaged 5 to 10 inches deeper than in the partial-cut areas and 13 to 16 inches deeper than in the uncut stand (table 7). Snow melted earliest on the north side of the clearcut areas and latest in the uncut stand. During the period covered by these measurements, an appreciable amount of ground in the clearcut areas was free of snow cover by April 15, and snow had completely disappeared from the uncut stands and the south edges of openings by the middle of May. This same trend has been reported for black spruce swamp cuttings in northern Minnesota (Weitzman and Bay, 1959).

TABLE 7. — *Average depth of maximum snowpack at Dukes*

(in inches)

Cutting method	Date				Average
	3-13-58	3-9-59	3-17-60	3-9-61	
Uncut	28	34	42	31	34
Selection	38	40	46	34	40
Diameter limit	38	42	52	38	42
Shelterwood	42	42	48	35	42
Clearcut strip	45	51	57	45	50
Clearcut block	45	47	54	40	47

The data on seedbed moisture conditions show that hardwoods were dominant on a larger proportion of the dry seedbeds (70 percent) than on wet ones (60 percent), but the reverse was true for conifers, the figures being 23 and 27 percent respectively. The smaller proportion of dry seedbeds in the clearcut methods might help account for their slight advantage over partial cuts in conifer abundance and distribution.

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FIGURE 10. — Snow pole in a shelterwood stand at Dukes showing 50 inches of snowpack (the 5-foot pole is marked at 3-inch intervals). A series of 60 poles observed for 4 winters showed that the average maximum snow depth increased 6 to 8 inches when the overstory was partially cut and 13 to 16 inches when it was completely removed in strips or blocks.

Biological Factors

Competing Vegetation

Although conifer regeneration may become established within the first year after cutting, it is often suppressed by hardwood and brush competition for many years.[3] An evaluation of this competition showed it was present in 75 to 80 percent of the milacre quadrats and 30 percent were over 3 feet tall 5 years after cutting. There were no differences in stocking among the cutting methods studied.

Mountain maple was the most widely distributed species of brush competition in the uncut stand and was still the most widespread in all cutting methods after 5 years (table 8). None of the

[3] *The term "brush" as used here includes both woody shrubs and unmerchantable hardwood tree species as shown in table 8.*

TABLE 8. — *Percent of milacres stocked with brush species at Dukes 5 years after cutting*

Species	Cutting methods					
	Uncut	Selection	Diameter limit	Shelterwood	Clearcut strip	Clearcut block
Mountain maple	73	52	59	61	34	30
Speckled alder	17	8	6	17	23	20
Ribes	13	18	21	15	14	18
Dogwood	7	8	6	12	24	16
Honeysuckle	12	8	8	4	1	4
Rubus	0	3	16	1	7	16
Willow	0	7	7	3	8	5
Cherry	0	0	1	0	1	1
Hazel-nut	1	1	1	1	0	1

other species was found on more than 25 percent of the area in any of the cuttings. Speckled alder was the second most frequent species in the even-aged cutting methods and ribes in the uneven-aged methods. Dogwood was more prevalent in the even-aged cutting methods than in the uneven-aged methods and honeysuckle was more common in the uncut stand. Brambles (*Rubus* spp.) and willow were scattered throughout all cutting methods but were not found in the uncut stand.

Growth of established conifer regeneration can be increased by releasing it from overtopping brush and hardwood competition. In another study at the Upper Peninsula Experimental Forest, the average height growth of seedlings during the first 5 years after release was 32 to 93 percent more than that of the seedlings that were not released (table 9). Balsam fir showed the greatest response and northern white-cedar the least. Black spruce was intermediate, with 68 percent increase in height growth. Before release, black spruce and balsam fir averaged 3.0 feet and northern white-cedar 4.5 feet in height. They were overtopped with speckled alder and mountain maple.

TABLE 9. — *Average growth of trees during first 5 years after release compared to growth of overtopped trees*

Species	Average annual height growth		
	Overtopped	Released	Increase
	Feet	*Feet*	*Percent*
Balsam fir	0.22	0.43	93
Black spruce	0.22	0.37	68
Cedar	0.22	0.29	32

With the amount of shrub and hardwood tree species present in all of the cutting methods tested and the favorable results obtained by releasing conifers from overtopping competition, the possibility of release as a regular management practice should be considered. Cutting the overtopping shrubs and hardwoods would involve a large number of stems in most cases. A more economical way might be with the use of a silvicide.

Animals

Mixed conifer swamps in the Lake States often support large populations of whitetail deer and snowshoe hare (Thornton, 1957a). In some stands the populations exceed the carrying capacity, and over-browsing severely restricts or eliminates the reproduction, especially that of northern white-cedar. In study area *A* at Dukes, however, no difference was observed between the reproduction protected and that unprotected from deer and hare. The population of deer on the Experimental Forest in 1959 was 15 animals per square mile as determined by a pellet survey. No estimate of the hare population on the study area is available, but it can be asserted that neither the snowshoe hare nor the whitetail deer had an appreciable effect on the overall regeneration. No data were collected on the protected and unprotected reproduction at the other study areas, but observations indicate that the effects of browsing were no greater than those found on study area *A*.

Krefting (1962) studied the relative deer use among the cutting methods in the two stands at Dukes and found that in the partial cuttings it increased with the intensity of the cut. The clearcut blocks had the least evidence of deer use. The results in the strip cuttings were variable; use was high in the uncut strips and low in the clearcut strips.

Other animals also find both food and shelter in mixed conifer swamps, but their influence on the stand is more difficult to evaluate. Two examples illustrate some detrimental effects of the beaver and squirrel. Beavers dammed one of the streams draining the Amasa study and flooded the shelterwood cutting area. At the Dukes studies, squirrels clipped a large amount of the spruce cones before they ripened in 1956 when the seed crop was rated as good. Good seed crops were also recorded in 1958 and 1960; but losses caused by squirrels were minor.

GROWTH OF RESIDUAL STANDS

Classification of Residual Trees

A comparison of the basal area per acre by diameters before and after cutting shows the changes in stand structures caused by the three partial cutting methods at Dukes (fig. 11). The differences in growth and mortality among the cutting methods were caused by the differences in both the density of the residual stand and the type of trees left.

Trees in the three partial cutting methods (selection, diameter limit, and shelterwood) and in the uncut stand were classified prior to cutting by the Lake States tree vigor classification system, which is based on crown position and development (Gevorkiantz et al., 1943). Three classes are recognized: progressive, provisional, and regressive.[4]

The number of residual trees per acre in each of the three classes varied with the cutting method (table 10). The selection and diameter-limit cuttings left the same number of regressive trees per acre, but the selection method left a larger number of progressive and provisional trees. The shelterwood cutting method left about the same number of progressive and provisional trees per acre as the diameter-limit cutting but only about one-third as many regressive trees.

Growth

The net growth during the first 5 years after cutting was less in cut stands than in the uncut stand. Part of this was due to the reduction in the growing stock and part was due to higher mortality in the cut stands (table 11). Both the diameter-limit and shelterwood cutting methods had negative net growth. The selection cutting had the most gross growth, but net growth was only three-fourths of that in the uncut stand because of increased mortality after cutting.

Although this study indicates that partial cutting in mixed conifer swamps is not justified from the standpoint of growth, younger stands have shown favorable results. A 45-year-old stand in the eastern end of the Upper Peninsula had 320 trees per acre over 5 inches d.b.h. 10 years after a heavy thinning compared to only 80 trees that large in the unthinned plot (Roe, 1947). However, a similar thinning in a 60-year-old stand was not beneficial, but the reason for this was thought to be poor drainage. In northern Wisconsin, growth per acre was greatest in the densest plots in a 65-year-old mixed conifer swamp stand, but diameter growth of individual trees responded to a 10-year-old improvement cutting to such an extent that good growth was recorded for all stand densities from 90 square feet of basal area per acre to over 200 (Skilling, 1959).

Differences between the growth obtained in this study and that reported elsewhere may be partially due to stand ages, conditions, sites, and the shorter growth period (5 years) used. The growth may well increase in some of these cutting methods after the trees are fully adjusted to their new growing space. A reduction in mortality might also be expected, which would increase the net growth.

Mortality

An average of 23 trees per acre was lost by mortality during the first 5 years after cutting (table 12). Mortality ranged from 13 trees per acre in the uncut stand to 33 trees per acre in the diameter-limit cutting.

More than 40 percent of the mortality (number of trees) in the uncut stand as well as in each of the partial cutting methods was the result of windthrow and breakage (fig. 12). Other types of mortality included logging injury and exposure.

More mortality occurred in each of the partially cut stands than in the uncut stand. Although the

[4]

Progressive	1. *Head dominants*	*Dominating surrounding trees.*
	2. *Strong dominants*	*Competing with trees of same crown class but poorer development.*
Provisional	3. *Conditional dominants and codominants*	*Competing with trees of same crown class on equal footing.*
Regressive	4. *Weak dominants and codominants*	*Competing with trees of same crown class but better developed.*
	5. *Intermediate*	*Competing with trees of higher crown class.*
	6. *Suppressed*	*Overtopped.*

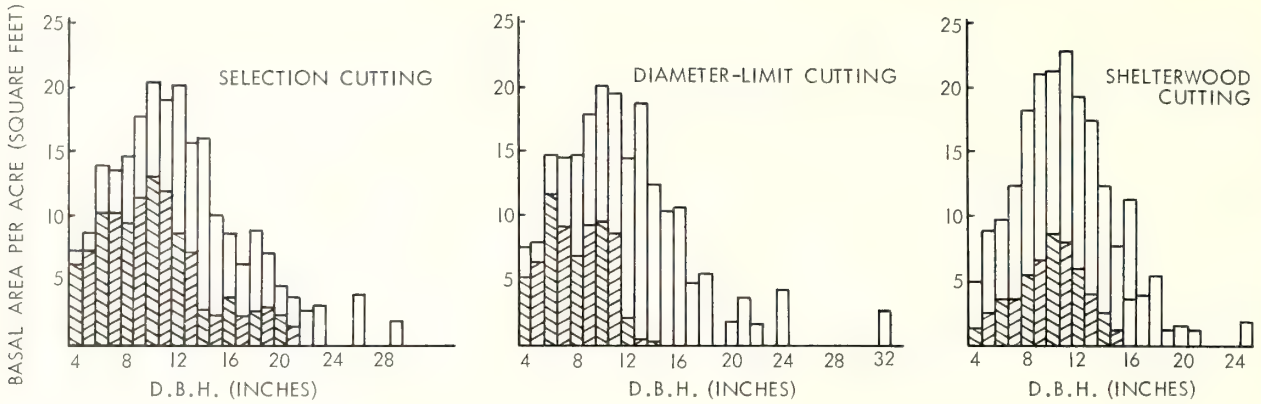

FIGURE 11. — Effects of partial cutting methods on stand structure in the study areas at Dukes. Shaded portions of graphs represent the residual stand.

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FIGURE 12. — The shallow roots of black spruce and brittle wood of balsam fir were factors in the two types of mortality caused by wind-uprooting and breaking. About 40 percent of the mortality during the first 5 years was caused by wind.

TABLE 10. — *Number and percentage of residual trees 3.6 inches d.b.h. and larger per acre by tree class, Dukes study area*

Class	Cutting method							
	Uncut		Selection		Diameter limit		Shelterwood	
	No.	*Percent*	*No.*	*Percent*	*No.*	*Percent*	*No.*	*Percent*
Progressive	128	29	71	21	47	17	44	31
Provisional	68	15	75	23	40	15	37	26
Regressive	251	56	188	56	188	68	60	43
Total	447	100	334	100	275	100	141	100

TABLE 11. — *Effect of cutting methods on basal area of residual stands during first 5-year period, Dukes study area*[1]

(*In square feet*)

Cutting method	Overstory basal area per acre[2]			Annual change per acre		
	Before	After	5th year	Net	Mortality	Gross[3]
Uncut	189.2	189.2	194.0	.96	1.06	2.02
Selection	223.2	115.4	119.0	.72	1.65	2.37
Diameter limit	205.3	71.2	69.6	—.32	1.53	1.21
Shelterwood	199.9	57.1	56.7	—.08	1.30	1.22

[1] *Clearcut blocks and strips are excluded since they had no residual stand.*
[2] *Includes all trees 3.6 inches d.b.h. and over.*
[3] *This column shows the annual change that would have occurred if no trees had died.*

TABLE 12. — *Summary of mortality per acre during first 5 years after cutting, by cutting method and tree class*

(*Number of trees*)

Class	Cause of mortality	Cutting method				Average
		Uncut	Selection	Diameter limit	Shelterwood	
Progressive	Wind	1.5	1.5	2.2	3.0	2.0
	Other	2.0	1.4	2.2	3.5	2.3
	Total	3.5	2.9	4.4	6.5	4.3
Provisional	Wind	0.0	4.4	4.3	1.5	2.6
	Other	0.5	3.2	0.4	0.5	1.1
	Total	0.5	7.6	4.7	2.0	3.7
Regressive	Wind	4.8	5.3	8.5	4.0	5.6
	Other	4.4	13.1	15.7	5.0	9.6
	Total	9.2	18.4	24.2	9.0	15.2
Total	Wind	6.3	11.2	15.0	8.5	10.2
	Other	6.9	17.7	18.3	9.0	13.0
	Total	13.2	28.9	33.3	17.5	23.2

number of trees lost per acre was the greatest in the diameter-limit cutting, the greatest loss in basal area was in the selection cutting (table 11). The estimated volumes lost by mortality during the 5-year period were 0.33 cord per acre in the selection cutting, 0.31 cord in the diameter limit, 0.26 cord in the shelterwood, and 0.21 cord in the uncut stand.

The average mortality for all stands by tree class was 4 progressive, 4 provisional, and 15 regressive trees per acre during the 5-year period. The fact that regressive trees made up the greatest proportion of the mortality explains some of the differences between the cutting methods. In the uncut and selectively cut stands, 56 percent of the residual trees were regressive; after the diameter-limit cut, 68 percent were regressive; and after the shelterwood cut, 43 percent. In general the shelterwood cutting method removed the greatest proportion of regressive trees, the diameter-limit cutting left the most, and the selection cutting method removed trees in about the same proportion as they occurred in the original stand.

RECOMMENDATIONS

The results observed during the first 5 years in this study have established some basic relationships that are useful in the development of silvicultural prescriptions for mixed conifer swamps. As described earlier in this report, the type is composed of a complex mixture of species and shows a strong tendency toward ecological change. Assuming that it is desirable to keep a high proportion of conifers on these sites, the natural succession must be held somewhere between the shrubs and the hardwood tree species. The even-aged cutting methods were the most successful in this respect. Conifer regeneration made the best development and competing hardwoods the poorest development on the clearcut blocks and strips. The shelterwood method was also more favorable for the conifers than either of the uneven-aged methods tested, but hardwood competition was greater than on the clearcut blocks or strips.

It is apparent, then, that even-aged management holds the most promise for regenerating conifers in the mixed conifer swamp type.

Determination of rotation age is a major problem in the application of even-aged systems in this type because some species reach maturity at a much earlier age than others. Stands with a high proportion of balsam fir must be cut at a relatively young age compared to stands consisting mostly of spruce or cedar. In stands where balsam fir is a significant component in mixture with spruce and cedar a compromise must be made between harvesting the balsam before losses become excessive and keeping spruce and cedar through their most productive growth period. A compromised managerial rotation age of 80 years has been suggested in a cutting guide prepared by the Forest Service for these stands (Stout, 1961).

This guide, based primarily on early results of this study, recommends strip cutting. Narrow strips not exceeding one tree height in width are to be clearcut. Wider strips up to two tree heights are permissible providing 30 square feet of basal area per acre in dominant conifers of good genetic characteristics are left as a shelterwood overstory.

These recommendations were generally borne out by later analysis of the study. The major point not discussed in the guide is the possibility of clearcutting in blocks or irregular patches instead of strips. Since the results in terms of conifer establishment and growth were as good on blocks as on strips, it would appear that these two methods are equally applicable. The choice of method should depend on the condition of the stand. In uniform stands it will usually be more advantageous to clearcut strips. In many stands, however, natural mortality or past stand treatment has already created a number of age classes in irregular patches. Block or patch cuttings could take better advantage of this natural age distribution than could regularly spaced strips.

Clearcut openings should be small. Observations of numerous cuttings in this type indicate that clearcutting large areas usually results in extensive brush invasion. Considerable time is often required before the conifer species again occupy these sites. The size of openings used in this study provides a guide until more information is available. Blocks are 2 chains square, and strips are 75 feet wide.

Observations of regeneration and measurements of the environmental factors suggest that a northerly exposure is the most favorable for swamp conifer regeneration. This can be accomplished by cutting east-west strips with subsequent strip cuttings progressing toward the south. Similarly block cuttings should progress from north to south in each stand.

Shelterwood cutting is recommended for small areas of swamp where it is impractical to use clearcut blocks or strips. A residual stand of 60 square feet of basal area per acre should be left after the initial cut. Well-developed dominant and codominant trees uniformly spaced over the area should be selected on the basis of windfirmness, seed production, and tree quality. They should remain until a good stand of conifer regeneration is established, approximately 10 years.

Although the recommended cutting practices create the most favorable conditions for the establishment and growth of conifer regeneration, hardwood competition if not controlled is likely to retard growth, especially in the shelterwood method. Release of established conifer seedlings from 5 to 10 years after cutting will ensure satisfactory development. Competition is generally not limiting until the fifth year, but after the tenth year conifer growth may be reduced considerably. Techniques for releasing the swamp conifers have not been studied, but chemical control methods seem to offer the best possibility for reducing the large number of hardwood stems present in the swamps at minimum cost.

These recommendations are based on observations and experience in conjunction with the results of this study. Most of the evidence supports the recommendation for even-aged management. A lesser amount of evidence is available for the specific applications discussed, and they will undoubtedly be modified when more detailed information is acquired on the effects of opening size, shape, and orientation, and the density and composition of the shelterwood overstory.

SUMMARY

The mixed conifer swamp forests occupy the wet depressions and drainageways in the northern hardwood forest region. They vary in species composition, but one or more of the conifers, northern white-cedar, black spruce, white spruce, balsam fir, or tamarack, are always predominant. The species in the surrounding types are generally scattered throughout the swamp. The strong tendency toward a change in species composition is one of the major problems in regenerating the swamp forests. The hardwood species growing in the swamps are usually very aggressive but highly defective and poor in quality. Conifers are generally more desirable than hardwoods, but do not regenerate as prolifically nor grow as fast in their juvenile years.

A survey of the regeneration on cutover swamplands in the Upper Peninsula of Michigan made in 1951 showed that under existing logging practices, the proportion of conifers in the reproduction stand was less than that in the original stand. This indicated that these practices were inadequate to ensure continuous high production in swamplands. Therefore between 1952 and 1955 several experimental cuttings, including both even-aged and uneven-aged methods, were made on five study areas. The even-aged methods tested were clearcutting in small blocks, clearcutting in narrow strips, and a two-cut shelterwood. The uneven-aged methods were selection and diameter-limit cuttings.

Advance reproduction was generally present in all study areas, but most of it was small and not well established. The two clearcutting methods resulted in the greatest losses of advanced reproduction because of logging, exposure, and slash accumulation. However, they also released more advanced reproduction from overtopping trees than did any of the other cutting methods.

Five years after cutting, the distribution, density, and composition of conifer regeneration were best in the clearcut blocks. Clearcutting in strips was the next most successful followed in order by shelterwood, diameter limit, and selection. All cutover areas except those cut by the selection method were over 60-percent stocked with conifer regeneration. The area cut selectively was 51-percent stocked with conifers, which is probably adequate for this type of cutting if subsequent cuts have similar results.

All cutting methods tested encouraged the invasion of hardwoods, but partial cutting over the entire stand increased their abundance and size

more than did clearcutting portions of the stand. A study of the environment associated with the cutting methods showed differences in overhead shade, temperatures, and moisture, which explains some of the variation in early development of the reproduction.

Competition from shrub species also retards the development of conifer regeneration. Methods for dealing with this problem have not yet been tested, but growth studies have shown that release can increase the height growth of white-cedar by 32 percent, black spruce by 68 percent, and balsam fir by 93 percent. Use of silvicides to control both brush and hardwood competition should be considered.

The partially cut stands in this study made very little growth during the first 5 years after the cut. All but the selectively cut stands showed a net loss in basal area because of post-cutting mortality. Forty percent of this mortality in all cutting methods was caused by wind. Losses were greatest in the residual stands that had a high proportion of trees with suppressed and poorly developed crowns and least where the proportion of dominant and well developed crowns was highest.

Cutting recommendations to obtain conifer regeneration based on these results would generally favor clearcutting in small blocks or narrow strips. The shelterwood method, however, may be more appropriate in small areas of the swamp type. It will probably still be necessary to control shrubs and hardwoods in some areas to ensure a conifer stand.

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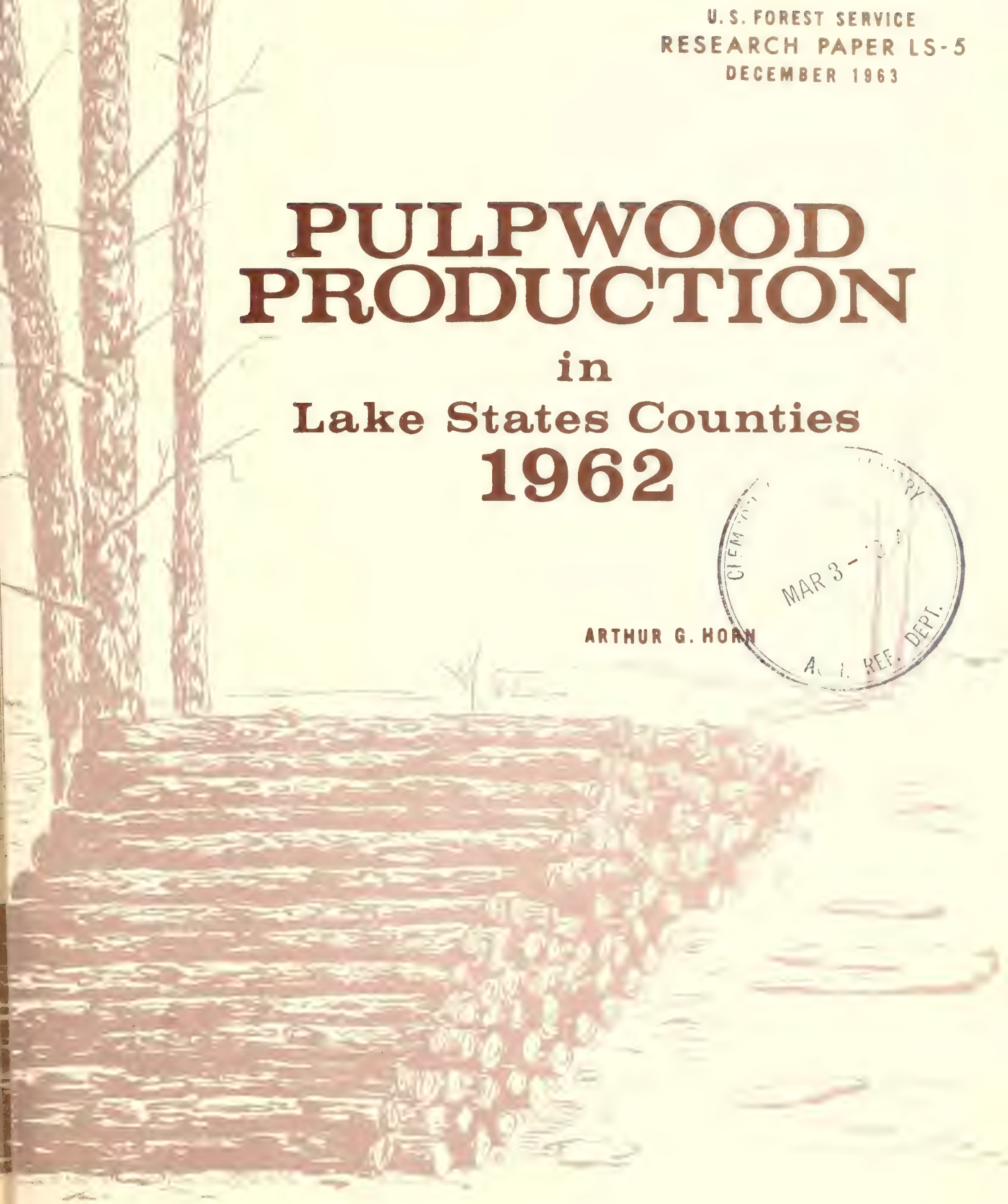
DECEMBER 1963

PULPWOOD PRODUCTION in Lake States Counties 1962



MAR 3 -

ARTHUR G. HORN

LAKE STATES FOREST EXPERIMENT STATION
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U. S. DEPARTMENT OF AGRICULTURE

CONTENTS

Page

About This Report 1

1962 Pulpwood Briefs 1

Pulpwood Production by State of Origin and Destination, Past Five Years 5

Pulpwood Production by Forest Survey Districts and Destination by States, 1962 6

Pulpwood Production by Species, State, and Forest Survey District for Specified Years 7

Pulpwood Production by County and Species, 1962

Wisconsin 12

Michigan 14

Minnesota 16

PULPWOOD PRODUCTION IN LAKE STATES COUNTIES, 1962

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M. B. Dickerman, Director
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The Station is maintained in cooperation with
the University of Minnesota

Four abstract cards are included at the back
of this report for the reader's convenience.

ABOUT THIS REPORT

Timber cutting rates vary from year to year. Frequent measurement is required to maintain a current, meaningful picture of the relationships between timber cut, timber growth, and desirable cut. To partially meet this need the Station publishes summaries of the output of various timber products as often as reliable data can be accumulated. Reports of pulpwood output by States have been published each year since 1946.

This is the fourth annual report on the pulpwood harvest by counties in the Lake States Region. The 58 pulpmills using Lake States timber in 1962 furnished figures on their wood receipts by State and county of origin. Their help is gratefully acknowledged. Thanks are due also to Ray Pfeifer, Forest Survey Coordinator, Michigan Department of Conservation, for collecting data for the Michigan pulpmills.

1962 PULPWOOD BRIEFS

Lake States pulpwood harvest reaches a new high. — Pulpwood production in the Lake States was 3,342,400 cords in 1962. This was an increase of 6 percent over 1961 and slightly more than the previous all-time high recorded in 1960. Pulpwood from roundwood accounted for 98 percent of the total cut; the remaining 2 percent was in wood chips, slabs, and veneer cores. Local timber operators cut and delivered pulpwood to 58 pulpmills: 51 in the Lake States, 4 in the Central States, and 3 in Canada. Exports to Central States mills were about equally divided between roundwood and chipped wood, while exports to Canadian mills were entirely roundwood.

Receipts of miscellaneous dense hardwoods and aspen were up 11 percent and 8 percent respectively over 1961. The cut of softwoods as a group declined about 1 percent. Chipped wood and unchipped plant residues delivered to pulpmills from sawmills and other primary wood-using plants amounted to nearly 65,000 cords — an increase of 52 percent over the preceding year.

A little more than half of the pulpwood harvested from Lake States forests was cut from private lands as shown below:

	Percent of pulpwood production
National Forest	18
Other Federal	2
State	15
County	8
Private	57
Total	100

Industrial forest owners harvested nearly one-half million cords of pulpwood from their lands, about 15 percent of all pulpwood production. The cut from industrial forest lands was largest in Wisconsin with about 240,000 cords, next in Michigan with 150,000 cords, and third in Minnesota with 110,000 cords.

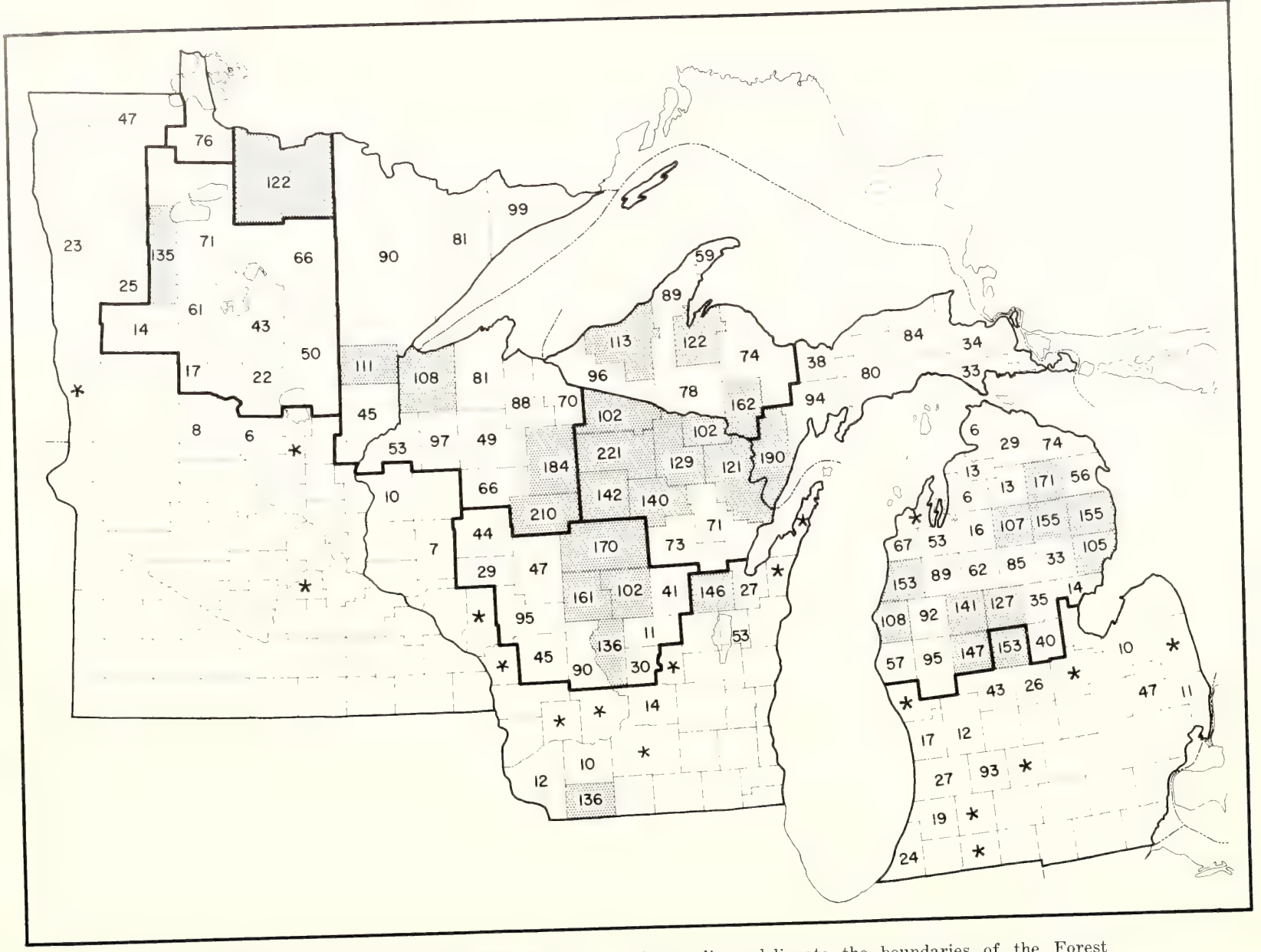
The number of mills using the different species of wood for pulping in 1962 is shown below.

Species and kind of material	Lake States	Minn.	Wis.	Mich.
Aspen	47	9	27	11
Balsam fir	30	6	19	5
Birch	13	2	9	2
Hemlock	9	—	9	—
Pine	15	6	5	4
Spruce	30	6	19	5
Tamarack	4	—	4	—
Misc. hardwoods	18	2	11	5
Wood chips (mixed species)	7	1	6	—
Slabs, etc. (mixed species	2	—	2	—
Total mills	51	10	29	12

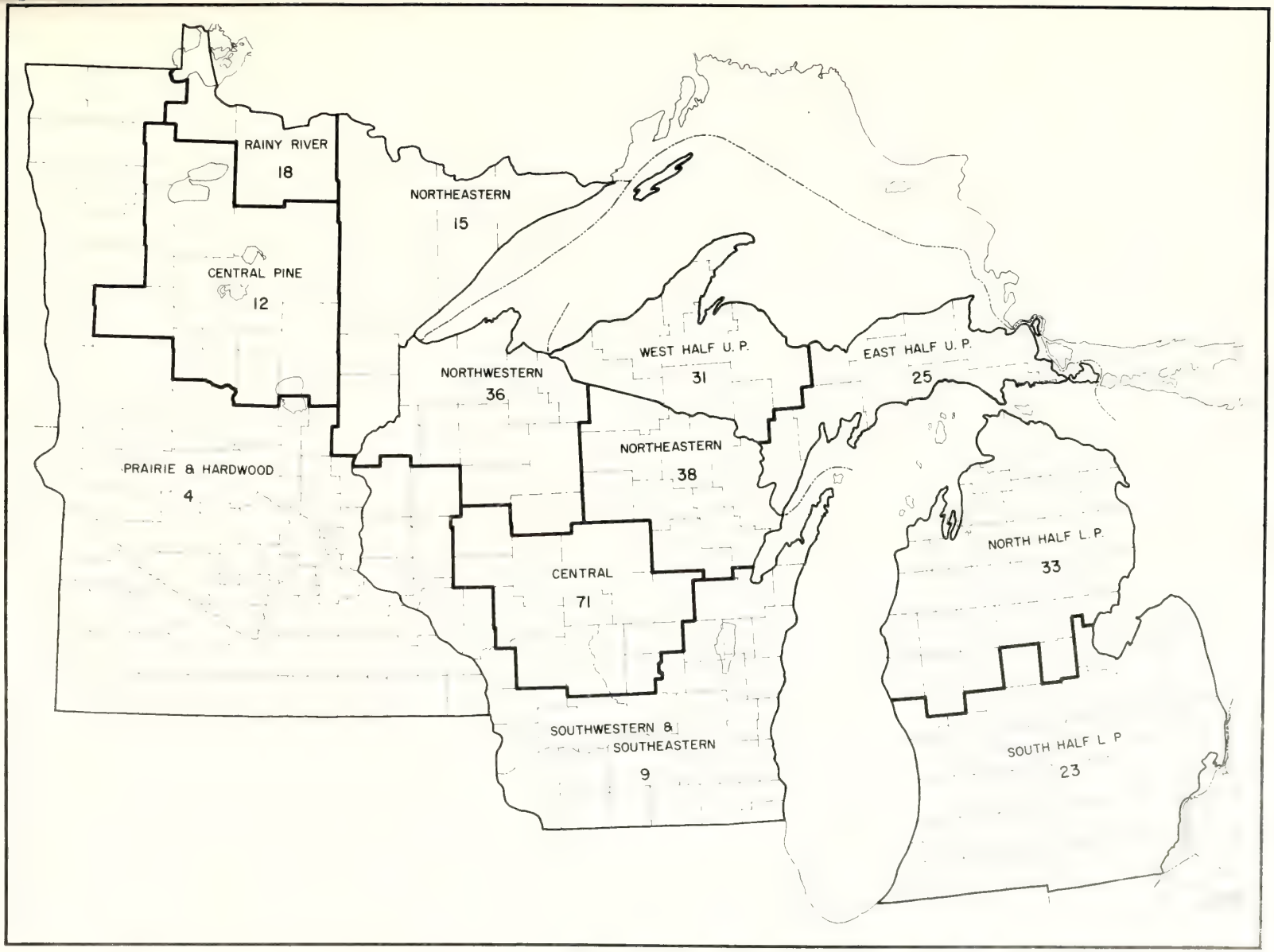
As in all recent years, aspen was first, followed by spruce and balsam fir. Eight Lake States mills procured wood chips and unchipped mill residues in 1962, compared to only 4 mills in 1961.

Michigan still the leading producer. — Michigan, with a pulpwood harvest of 1,223,293 cords, was again the Lake States leading producer. The harvest was 11 percent larger than the previous year and 60 percent larger than 10 years ago. About 677,000 cords (55 percent) were delivered to Michigan mills, 540,000 cords (44 percent) were exported to Wisconsin, and 6,000 cords (1 percent) went to the Central States.

Aspen, pine, and hard hardwoods were the species most heavily cut in Michigan. The aspen pulpwood harvest amounted to approximately 601,000 cords, an increase of 43,000 cords over the previous year. Menominee, Alcona, and Dickinson Counties yielded the largest cuts. Pine production amounted to 184,000 cords, an increase of 28,000



Cords of pulpwood cut per 1,000 acres of stocked commercial forest land in the principal pulpwood-producing counties, Lake States, 1962. Cross-hatching shows counties that supplied 100 or more cords of pulpwood per 1,000 acres of stocked commercial forest land. The heavy lines delineate the boundaries of the Forest Survey districts in each State. The asterisk (*) indicates a pulpwood production of less than 5 cords per 1,000 acres.



Cords of pulpwood cut per thousand cords of merchantable volume in principal pulpwood species, by Forest Survey district, 1962. Note: Minnesota figures are not comparable to those published in previous pulpwood reports. They are based on new findings from the third Minnesota Forest Survey which show substantially increased timber volumes.

cords. Oscoda, Crawford, Luce, and Marquette Counties yielded the largest cuts of pine. The cut of pulpwood from dense hardwood species amounted to 144,000 cords, up about one-third over the previous year. Ontonagon, Manistee, and Houghton Counties furnished the largest amounts.

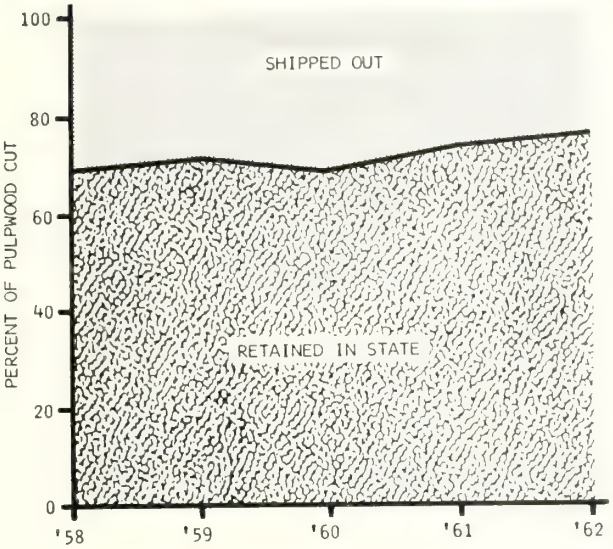
Wisconsin's annual output continues steady climb. — The Wisconsin pulpwood cut amounted to 1,140,347 cords in 1962. The harvest was up 6 percent from the previous year and nearly double that of 10 years ago. Nearly all of the pulpwood cut in the State went to Wisconsin mills; exports to Minnesota, Michigan, and the Central States amounted to only 27,000 cords. Wisconsin has never been a large exporter of pulpwood. Only during the past few years have exports gained, mainly because of larger deliveries of hardwood roundwood to Central States mills. Most of this wood was cut in Grant, Lafayette, and Monroe Counties.

Aspen, hard hardwoods, and pine made up most of the pulpwood harvest in 1962. Aspen was the leading species with approximately 572,000 cords, an increase of 42,000 cords over the previous year. Oneida, Price, and Forest Counties yielded the largest cuts of aspen. Dense hardwoods amounted to 188,000 cords, slightly less than the previous year. Marathon, Taylor, and Price Counties furnished the largest amounts. Pine production was also 188,000 cords, an increase of 34,000 over the previous year. Douglas, Jackson, and Washburn Counties yielded the largest cuts of pine.

Minnesota's annual production has leveled off at about 1 million cords. — For the seventh consecutive year Minnesota's annual pulpwood output has approximated one million cords. The 1962 harvest was 978,733 cords, 1 percent larger than the previous year and 4 percent larger than that of 10 years ago. Although Minnesota's pulpwood output has not followed the strong upward trend so evident in Michigan and Wisconsin, local plant facilities have been expanded and as a result more of Minnesota's pulpwood cut has been delivered to Minnesota mills. Station records show progessively larger amounts of local pulpwood being retained in the State each year. In 1962 about 753,000 cords, 77 percent of the total, were delivered to state mills. Exports to Wisconsin, Michigan, and Canada amounted to 226,000 cords, 12 percent less than the previous year.

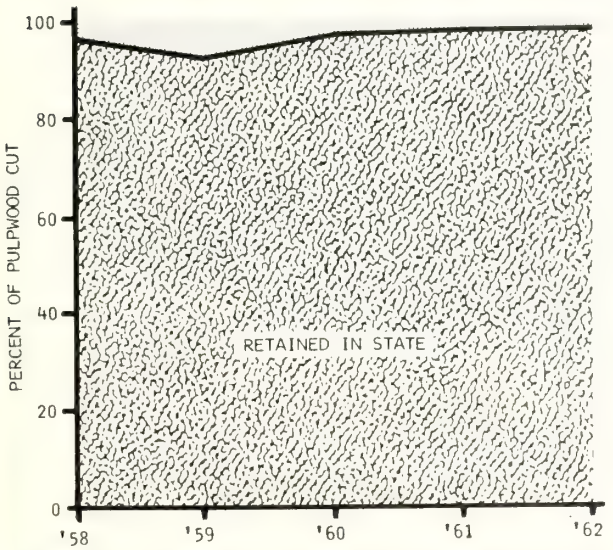
Aspen, spruce, and pine were the species most heavily cut in 1962. The aspen cut amounted to approximately 406,000 cords, an increase of 37,000 cords over the 1961 output. St. Louis, Koochiching, and Itasca Counties yielded the largest cuts. Spruce production was 217,000 cords, a decrease of about 10 percent. Koochiching, St. Louis, and Cook Counties were the leaders. The pine output amounted to 201,000 cords, practically the same as the previous year. St. Louis, Lake, and Cook Counties yielded the largest cuts of pine.

PULPWOOD PRODUCTION BY STATE OF ORIGIN AND DESTINATION PAST FIVE YEARS



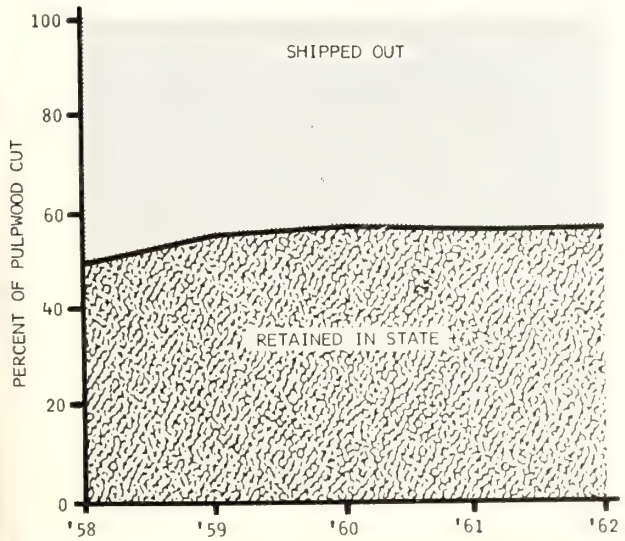
MINNESOTA

Year	Total cut	Destination of pulpwood			
		Minn.	Wis.	Mich.	Other
	(Thousand standard cords)				
1958	903	626	267	7	3
1959	994	721	251	7	15
1960	1,048	711	308	-	29
1961	968	712	240	-	16
1962	979	753	216	1	9
5-year average	978	705	256	3	14



WISCONSIN

Year	Total cut	Destination of pulpwood			
		Minn.	Wis.	Mich.	Other
	(Thousand standard cords)				
1958	828	14	811	-	3
1959	972	21	915	3	33
1960	1,052	19	1,008	-	25
1961	1,078	14	1,050	1	13
1962	1,140	15	1,114	1	10
5-year average	1,014	17	980	1	17



MICHIGAN

Year	Total cut	Destination of pulpwood			
		Minn.	Wis.	Mich.	Other
	(Thousand standard cords)				
1958	900	-	442	458	-
1959	1,053	-	447	603	3
1960	1,237	-	510	727	-
1961	1,106	-	464	628	14
1962	1,223	-	540	677	6
5-year average	1,104	-	481	569	3

PULPWOOD PRODUCTION BY FOREST SURVEY DISTRICTS AND DESTINATION BY STATES, 1962

(Thousand standard cords, roughwood basis)

MINNESOTA

District	Total cut	Destination of pulpwood			
		Minnesota	Wisconsin	Michigan	Other
Northeastern	458	280	174	1	3
Central Pine	305	266	39	-	-
Rainy River	200	191	3	-	6
Hardwood & Prairie	16	16	-	-	-
Total	979	753	216	1	9

WISCONSIN

District	Total cut	Destination of pulpwood			
		Minnesota	Wisconsin	Michigan	Other
Northeastern	466	-	465	1	-
Northwestern	443	15	428	-	-
Central	211	-	208	-	3
Southeastern & Southwestern	20	-	13	-	7
Total	1,140	15	1,114	1	10

MICHIGAN

District	Total cut	Destination of pulpwood			
		Minnesota	Wisconsin	Michigan	Other
E. ½ Up. Pen.	278	-	211	67	-
W. ½ Up. Pen.	426	-	329	91	6
N. ½ Low. Pen.	486	-	-	486	-
S. ½ Low. Pen.	33	-	-	33	-
Total	1,223	-	540	677	6

PULPWOOD PRODUCTION BY SPECIES, STATE, AND FOREST SURVEY DISTRICTS FOR SPECIFIED YEARS

(Thousand standard cords, roughwood basis)

ASPEN

State and district	Annual production			
	1959	1960	1961	1962
MINNESOTA:				
Northeastern	119	150	152	170
Central Pine	169	158	137	146
Rainy River	86	77	74	83
Prairie & Hardwood	7	7	6	7
Total	381	392	369	406
WISCONSIN:				
Northeastern	206	281	280	301
Northwestern	172	212	203	210
Central	51	45	46	54
Southeastern & Southwestern	2	2	1	7
Total	431	540	530	572
MICHIGAN:				
E. ½ Up. Pen.	94	111	91	96
W. ½ Up. Pen.	142	173	168	174
N. ½ Low. Pen.	263	355	280	305
S. ½ Low. Pen.	24	30	19	26
Total	523	669	558	601
Lake States	1,335	1,601	1,457	1,579

BALSAM FIR

State and district	Annual production			
	1959	1960	1961	1962
MINNESOTA:				
Northeastern	59	62	47	38
Central Pine	40	49	35	40
Rainy River	30	33	29	32
Prairie & Hardwood	1	1	*	-
Total	130	145	111	110
WISCONSIN:				
Northeastern	31	25	30	24
Northwestern	20	24	30	22
Central	1	1	1	*
Southeastern & Southwestern	*	-	*	*
Total	52	50	61	46
MICHIGAN:				
E. ½ Up. Pen.	57	73	58	56
W. ½ Up. Pen.	45	55	48	44
N. ½ Low. Pen.	7	7	9	4
S. ½ Low. Pen.	-	-	-	-
Total	109	135	115	104
Lake States	291	330	287	260

* Less than 500 cords.

(Cont'd on next page)

(Pulpwood production cont'd.)

(Thousand standard cords, roughwood basis)

State and district	JACK PINE[1/] Annual production				State and district	SPRUCE Annual production			
	1959	1960	1961	1962		1959	1960	1961	1962
MINNESOTA:					MINNESOTA:				
Northeastern	102	138	127	126	Northeastern	108	146	131	114
Central Pine	121	64	56	53	Central Pine	45	42	35	40
Rainy River	8	13	13	13	Rainy River	65	67	70	63
Prairie & Hardwood	8	10	9	9	Prairie & Hardwood	2	1	4	*
Total	239	225	205	201	Total	220	256	240	217
WISCONSIN:					WISCONSIN:				
Northeastern	47	38	42	42	Northeastern	13	11	13	8
Northwestern	56	53	35	71	Northwestern	7	6	10	6
Central	84	29	73	70	Central	1	1	*	1
Southeastern & Southwestern	-	4	4	5	Southeastern & Southwestern	-	-	-	*
Total	187	124	154	188	Total	21	18	23	15
MICHIGAN:					MICHIGAN:				
E. ½ Up. Pen.	59	51	38	61	E. ½ Up. Pen.	37	52	45	41
W. ½ Up. Pen.	33	22	13	29	W. ½ Up. Pen.	39	49	44	41
N. ½ Low. Pen.	104	114	103	93	N. ½ Low. Pen.	7	7	7	4
S. ½ Low. Pen.	1	1	2	1	S. ½ Low. Pen.	-	-	-	-
Total	197	188	156	184	Total	83	108	96	86
Lake States	623	537	515	573	Lake States	324	382	359	318

1/ Includes small quantity of red and white pine.

(Cont'd on next page)

* Less than 500 cords.

(Pulpwood production cont'd.)

(Thousand standard cords, roughwood basis)

State and district	BIRCH Annual production				State and district	HEMLOCK Annual production			
	1959	1960	1961	1962		1959	1960	1961	1962
MINNESOTA:					MINNESOTA:				
Northeastern	1	*	*	*	Northeastern	-	-	-	-
Central Pine	*	1	1	2	Central Pine	-	-	-	-
Rainy River	-	-	-	-	Rainy River	-	-	-	-
Prairie & Hardwood	-	-	-	-	Prairie & Hardwood	-	-	-	-
Total	1	1	1	2	Total	-	-	-	-
WISCONSIN:					WISCONSIN:				
Northeastern	4	4	12	4	Northeastern	18	17	18	21
Northwestern	22	19	21	31	Northwestern	26	27	25	18
Central	*	4	1	6	Central	5	8	4	3
Southeastern & Southwestern	-	-	*	-	Southeastern & Southwestern	-	-	*	*
Total	26	27	34	41	Total	49	52	47	42
MICHIGAN:					MICHIGAN:				
E. ½ Up. Pen.	3	3	6	5	E. ½ Up. Pen.	*	3	2	3
W. ½ Up. Pen.	1	2	5	3	W. ½ Up. Pen.	39	43	42	54
N. ½ Low. Pen.	-	4	5	13	N. ½ Low. Pen.	-	-	-	-
S. ½ Low. Pen.	-	-	-	-	S. ½ Low. Pen.	-	-	-	-
Total	4	9	16	21	Total	39	46	44	57
Lake States	31	37	51	64	Lake States	88	98	91	99

* Less than 500 cords.

(Cont'd on next page)

(Pulpwood production cont'd.)

(Thousand standard cords, roughwood basis)

State and district	TAMARACK Annual production				MISC. HARDWOODS Annual production			
	1959	1960	1961	1962	1959	1960	1961	1962
MINNESOTA:								
Northeastern	2	5	3	6	1	1	1	4
Central Pine	6	11	5	3	-	*	21	21
Rainy River	3	3	*	-	11	9	9	9
Prairie & Hardwood	-	-	*	-	-	-	3	*
Total	11	19	8	9	12	10	34	34
WISCONSIN:								
Northeastern	4	4	2	2	53	73	52	46
Northwestern	3	2	5	4	58	63	67	67
Central	-	*	*	*	47	61	74	69
Southeastern & Southwestern	-	-	-	*	1	7	8	6
Total	7	6	7	6	159	204	201	188
MICHIGAN:								
E. ½ Up. Pen.	*	2	2	3	4	4	2	13
W. ½ Up. Pen.	3	3	2	1	51	43	37	58
N. ½ Low. Pen.	-	-	-	-	28	16	46	67
S. ½ Low. Pen.	-	-	-	-	7	12	11	6
Total	3	5	4	4	90	75	96	144
Lake States	21	30	19	19	261	289	331	366

* Less than 500 cords.

(Cont'd on next page)

(Pulpwood production cont'd.)

(Thousand standard cords, roughwood basis)

State and district	RESIDUE & CHIPS 1/ Annual production				State and district	ALL SPECIES 2/ Annual production			
	1959	1960	1961	1962		1959	1960	1961	1962
MINNESOTA:					MINNESOTA:				
Northeastern	-	-	-	-	Northeastern	392	502	461	458
Central Pine	-	-	-	-	Central Pine	381	325	290	305
Rainy River	-	-	-	-	Rainy River	203	202	195	200
Prairie & Hardwood	-	-	-	*	Prairie & Hardwood	18	19	22	16
Total	-	-	-	*	Total	994	1,048	968	979
WISCONSIN:					WISCONSIN:				
Northeastern	18	13	9	18	Northeastern	394	466	458	466
Northwestern	13	10	7	14	Northwestern	377	416	403	443
Central	7	6	4	8	Central	196	155	203	211
Southeastern & Southwestern	2	2	1	2	Southeastern & Southwestern	5	15	14	20
Total	40	31	21	42	Total	972	1,052	1,078	1,140
MICHIGAN:					MICHIGAN:				
E. ½ Up. Pen.	-	-	-	*	E. ½ Up. Pen.	254	299	249	278
W. ½ Up. Pen.	5	2	21	22	W. ½ Up. Pen.	358	392	375	426
N. ½ Low. Pen.	-	-	-	-	N. ½ Low. Pen.	409	503	450	486
S. ½ Low. Pen.	-	-	-	-	S. ½ Low. Pen.	32	43	32	33
Total	5	2	21	22	Total	1,053	1,237	1,106	1,223
Lake States	45	33	42	64	Lake States	3,019	3,337	3,152	3,342

1/ Not reported by district. Prorated on basis of most recent lumber output figures.

2/ Including residues and chips.

* Less than 500 cords.

PULPWOOD PRODUCTION BY COUNTY AND SPECIES, 1962

WISCONSIN

(Thousand standard cords, roughwood basis)

District & county[1/]	All species	Aspen	Balsam	Birch	Hemlock	Pine	Spruce	Tamarack	Misc. hdwds.	Residue & chips[2/]
NORTHEASTERN:										
Florence	25	18	2	*	3	*	1	-	1	-
Forest	65	46	6	*	7	2	1	*	3	-
Langlade	48	33	3	*	1	*	1	*	10	-
Lincoln	46	30	1	*	1	8	*	*	6	-
Marinette	65	41	4	*	2	9	1	1	7	-
Oconto	26	19	1	-	1	2	1	-	2	-
Oneida	106	69	5	2	3	14	2	1	10	-
Shawano	26	22	1	*	1	*	*	-	2	-
Vilas	41	23	1	2	2	7	1	*	5	-
Total	466	301	24	4	21	42	8	2	46	18
NORTHWESTERN:										
Ashland	43	17	9	3	3	1	1	1	8	-
Bayfield	59	37	1	8	2	10	*	*	1	-
Burnett	15	1	-	*	-	14	*	*	*	-
Douglas	55	23	1	1	*	24	2	1	3	-
Iron	26	18	2	1	3	-	1	*	1	-
Price	88	49	5	9	4	*	1	*	20	-
Rusk	20	10	*	*	1	-	*	*	9	-
Sawyer	28	14	2	5	2	2	*	1	2	-
Taylor	63	33	1	3	3	-	1	*	22	-
Washburn	32	8	1	1	*	20	*	1	1	-
Total	443	210	22	31	18	71	6	4	67	14
CENTRAL:										
Adams	27	2	-	-	-	12	-	-	13	-
Chippewa	9	9	-	-	*	*	-	*	*	-
Clark	12	8	-	*	1	*	*	-	3	-
Eau Claire	4	2	-	*	-	2	-	-	-	-
Jackson	28	2	-	-	-	24	-	*	2	-
Juneau	20	4	-	-	-	14	-	-	2	-
Marathon	50	17	*	5	1	1	1	*	25	-
Marquette	2	*	-	-	-	*	-	-	2	-
Monroe	10	*	-	-	-	9	-	-	1	-
Portage	12	2	*	1	*	2	*	-	7	-
Waupaca	5	4	*	*	1	*	*	-	*	-
Waushara	1	*	-	-	-	*	-	-	1	-
Wood	23	4	-	*	*	6	-	-	13	-
Total	211	54	*	6	3	70	1	*	69	8

WISCONSIN (cont'd)

(Thousand standard cords, roughwood basis)

District & county[1/]	All species	Aspen	Balsam	Birch	Hemlock	Pine	Spruce	Tamarack	Misc. hdwds.	Residue & chips[2/]
SOUTHWESTERN:										
Dunn	1	*	-	-	-	1	-	-	-	-
Grant	2	-	-	-	-	1	-	-	1	-
Iowa	1	-	-	-	-	*	-	-	1	-
LaFayette	3	-	-	-	-	1	-	-	2	-
LaCrosse	*	-	-	-	-	*	-	-	-	-
Polk	2	*	-	-	-	2	-	*	-	-
Richland	*	-	-	-	-	*	-	-	-	-
Sauk	*	*	-	-	-	-	-	-	*	-
Trempealeau	*	-	-	-	-	*	-	-	-	-
Total	11	*	-	-	-	5	-	*	4	2
SOUTHEASTERN:										
Brown	1	1	*	-	*	*	*	-	*	-
Columbia	1	*	-	-	*	*	-	-	1	-
Door	*	-	*	-	-	-	-	-	*	-
Green Lake	*	-	-	-	-	*	-	-	-	-
Kewaunee	*	*	*	-	-	-	-	-	*	-
Outagamie	7	6	*	-	-	-	*	-	1	-
Total	9	7	*	-	*	*	*	-	2	*
State total	1,140	572	46	41	42	188	15	6	188	42

1/ Includes only those counties that supplied pulpwood in 1962.

2/ County figures are not available.

* Less than 500 cords.

MICHIGAN

(Thousand standard cords, roughwood basis)

District & county[1/]	All species	Aspen	Balsam	Birch	Hemlock	Pine	Spruce	Tamarack	Misc. hdwds.	Residue & chips[2/]
E. ½ UP. PEN.:										
Alger	18	1	2	*	*	12	3	*	-	-
Chippewa	24	2	4	1	-	11	5	1	-	-
Delta	54	24	10	2	1	7	3	*	7	-
Luce	37	1	4	1	*	21	9	1	-	-
Mackinac	17	4	8	*	*	2	3	*	-	-
Menominee	87	59	14	*	1	1	7	*	5	-
Schoolcraft	41	5	14	1	1	7	11	1	1	-
Total	278	96	56	5	3	61	41	3	13	-
W. ½ UP. PEN.:										
Baraga	58	32	7	*	1	3	10	*	5	-
Dickinson	60	38	9	1	1	1	6	1	3	-
Gogebic	49	22	3	*	21	*	1	*	2	-
Houghton	45	11	2	*	15	3	2	*	12	-
Iron	45	27	5	*	4	*	4	*	5	-
Keweenaw	11	*	6	-	-	-	5	-	-	-
Marquette	67	21	11	2	*	21	12	*	-	-
Ontonagon	69	23	1	*	12	1	1	*	31	-
Total	426	174	44	3	54	29	41	1	58	22
N. ½ LOW. PEN.:										
Alcona	48	39	*	2	-	1	*	-	6	-
Alpena	12	7	1	1	-	*	1	-	2	-
Antrim	1	1	-	*	-	*	-	-	*	-
Arenac	1	1	-	*	-	*	-	-	*	-
Benzie	7	5	-	*	-	*	-	-	2	-
Charlevoix	2	2	-	-	-	-	-	-	-	-
Cheboygan	9	6	1	*	-	1	1	-	*	-
Clare	22	22	*	*	-	-	*	-	*	-
Crawford	29	6	*	1	-	21	*	-	1	-
Emmett	1	1	-	*	-	-	-	-	*	-
Gladwin	5	5	-	*	-	*	-	-	*	-
Grand Traverse	6	4	-	*	-	2	-	-	*	-
Iosco	22	9	*	1	-	11	*	-	1	-
Kalkaska	3	2	*	-	-	1	*	-	-	-
Lake	26	10	*	1	-	10	*	-	5	-
Leelanau	*	*	-	-	-	*	-	-	-	-
Manistee	32	10	-	*	-	1	-	-	21	-
Mason	17	9	-	*	-	2	-	-	6	-
Mecosta	15	14	-	*	-	*	-	-	1	-
Midland	6	6	-	*	-	-	-	-	-	-
Missaukee	11	5	*	1	-	4	*	-	1	-
Montmorency	43	29	1	1	-	6	1	-	5	-
Newaygo	25	23	-	*	-	*	-	-	2	-
Oceana	7	7	-	*	-	*	-	-	*	-
Ogemaw	8	5	*	*	-	3	*	-	*	-
Osceola	21	16	-	1	-	*	-	-	4	-
Oscoda	44	19	*	1	-	23	*	-	1	-
Otsego	3	2	-	*	-	1	-	-	*	-
Presque Isle	20	12	1	2	-	1	1	-	3	-
Roscommon	22	17	*	1	-	2	*	-	2	-
Wexford	18	11	-	*	-	3	-	-	4	-
Total	486	305	4	13	-	93	4	-	67	-

MICHIGAN (cont'd.)

(Thousand standard cords, roughwood basis)

District & county[1/]	All species	Aspen	Balsam	Birch	Hem-lock	Pine	Spruce	Tam-arack	Misc. hdwds.	Residue & chips[2/]
S. ½ LOW. PEN.:										
Allegan	3	1	-	-	-	*	-	-	2	-
Barry	4	2	-	-	-	*	-	-	2	-
Berrien	1	*	-	-	-	-	-	-	1	-
Eaton	*	-	-	-	-	-	-	-	*	-
Gratiot	1	1	-	-	-	-	-	-	*	-
Isabella	11	11	-	-	-	*	-	-	*	-
Kalamazoo	*	*	-	-	-	*	-	-	*	-
Kent	1	1	-	-	-	-	-	-	*	-
Lapeer	4	3	-	-	-	-	-	-	1	-
Montcalm	4	4	-	-	-	*	-	-	-	-
Muskegon	*	*	-	-	-	*	-	-	-	-
Ottawa	1	*	-	-	-	1	-	-	-	-
Saginaw	*	*	-	-	-	-	-	-	-	-
St. Clair	1	1	-	-	-	-	-	-	*	-
St. Joseph	*	*	-	-	-	-	-	-	*	-
Sanilac	*	*	-	-	-	-	-	-	-	-
Tuscola	1	1	-	-	-	-	-	-	*	-
Van Buren	1	1	-	-	-	-	-	-	*	-
Total	33	26	-	-	-	1	-	-	6	-
State total	1,223	601	104	21	57	184	86	4	144	22

1/ Includes only those counties that supplied pulpwood in 1962.

2/ Residue and chips were used for pulpwood only in the western half of the Upper Peninsula. Data by counties for this area are not available.

* Less than 500 cords.

MINNESOTA

(Thousand standard cords, roughwood basis)

District & county 1/	All species	Aspen	Balsam	Birch	Pine	Spruce	Tamarack	Misc. hdwds.	Residue & chips
NORTHEASTERN:									
Carlton	34	29	2	-	3	*	-	-	-
Cook	65	*	4	-	17	44	-	-	-
Lake	82	11	2	-	44	25	-	-	-
Pine	17	12	*	-	2	1	*	2	-
St. Louis	260	118	30	*	60	44	6	2	-
Total	458	170	38	*	126	114	6	4	-
CENTRAL PINE:									
Aitkin	35	28	3	-	2	2	*	*	-
Becker	5	3	1	-	1	*	-	-	-
Beltrami	58	27	8	1	9	9	1	3	-
Cass	39	14	5	1	11	3	1	4	-
Clearwater	44	25	3	*	2	2	*	12	-
Crow Wing	9	*	*	-	8	1	-	-	-
Hubbard	25	17	1	*	5	2	*	1	-
Itasca	87	32	19	*	13	21	1	1	-
Wadena	2	*	-	-	2	*	-	-	-
Total	305	146	40	2	53	40	3	21	-
RAINY RIVER:									
Koochiching	170	75	30	-	6	50	-	9	-
Lake of the Woods	30	8	2	-	7	13	-	*	-
Total	200	83	32	-	13	63	-	9	-
HARDWOOD:									
Mille Lacs	*	-	-	-	-	-	-	*	-
Morrison	1	-	-	-	1	*	-	-	-
Scott	*	-	-	-	-	*	-	-	-
Todd	1	-	-	-	1	-	-	-	-
Total	2	-	-	-	2	*	-	*	-
PRAIRIE:									
Mahnomen	3	3	-	-	-	*	-	-	-
Polk	2	2	-	-	-	-	-	-	-
Roseau	9	2	-	-	7	*	-	-	-
Wilkin	*	-	-	-	*	-	-	-	-
Total	14	7	-	-	7	*	-	-	-
State total	979	406	110	2	201	217	9	34	-

1/ Includes only those counties that supplied pulpwood in 1962.

* Less than 500 cords.

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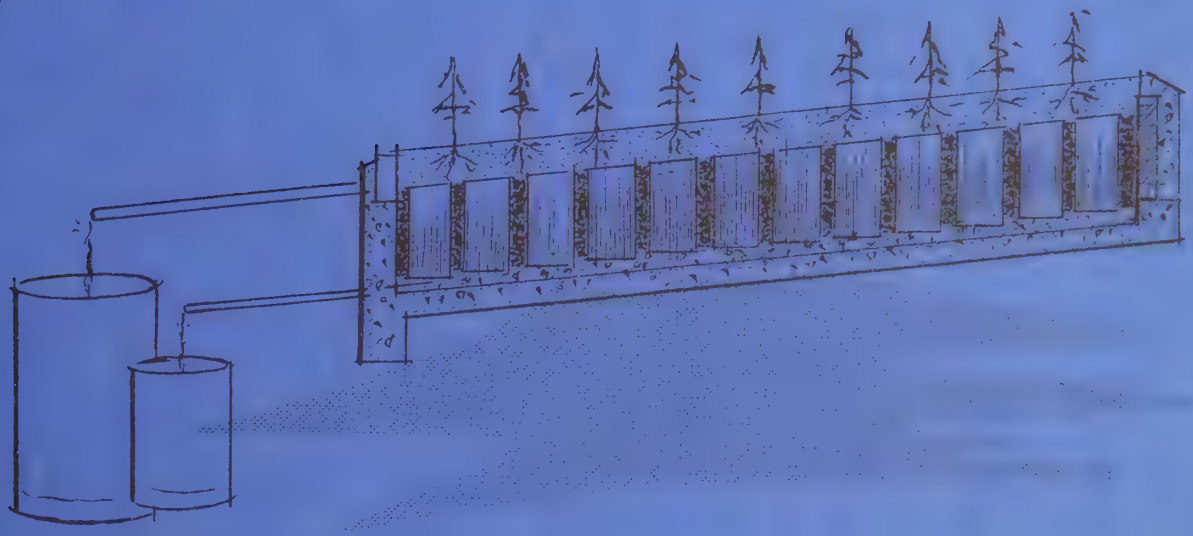
U. S. Forest Service
RESEARCH PAPER LS-6
December 1963

WATER YIELD and SOIL LOSS from SOIL-BLOCK LYSIMETERS

CLEMSON
MAR 3 -

RICHARD S. SARTZ



LAKE STATES FOREST EXPERIMENT STATION
M. B. Dickerman, Director
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

ACKNOWLEDGEMENTS

The study reported here was made between 1934 and 1942 by personnel of the Lake States Forest Experiment Station. Director of the Station at that time was Raphael Zon. The study was planned and supervised by Carlos G. Bates, a pioneer Forest Service researcher. Harold F. Scholz was in charge of on-the-ground operations. He was assisted in construction of the lysimeters by J. H. Stoeckeler. Day-to-day measurements and records-keeping for most of the study were handled by Robert G. Neu.

Mr. Scholz is currently Research Forester (Forest Management) at the Lake States Station's field unit in Wausau, Wis.; Dr. Stoeckeler is Soil Scientist with the Station at St. Paul; and Mr. Neu is Administrative Assistant with the Agricultural Research Service at Madison, Wis.

The work was done at the Upper Mississippi Valley Soil Conservation Experiment Station, near La Crosse, a cooperative research station conducted by the United States Department of Agriculture and the Wisconsin College of Agriculture.

Mr. Bates was engaged in writing up the study when he died in July 1949. After the Lake States Station began its current program of watershed management research in southwestern Wisconsin, the author undertook preparation of the final report on the lysimeter study.

Messrs. Scholz and Neu provided much of the information presented here through the annual reports they had prepared and by correspondence and discussion with the author on details and procedures not shown in the records. Bates' unfinished, first-draft manuscript, an unpublished manuscript by Scholz and Bates, and various file memoranda have also been the source of much useful information.

U.S. Forest Service
RESEARCH PAPER LS-6
December 1963

Water Yield and Soil Loss From Soil-Block Lysimeters Planted to Small Trees and Other Crops

By
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CONTENTS

Page

SUMMARY 1

INTRODUCTION 2

THE AREA AND STUDY OBJECTIVES 2

LITERATURE REVIEW 3

THE LYSIMETERS 3

- Construction 3
- Operation 4
- Pretreatment Testing of Lysimeters 5
- The Treatments 6

LIMITATIONS OF THE STUDY 7

ANALYSIS OF RECORDS 8

- Effect of Treatment and Time 8
  - On Runoff 9
  - On Percolation 13
  - On Soil Loss 13
- Distribution and Duration of Percolation 16
- The Annual Water Budget 17

EVALUATION OF THE STUDY 21

LITERATURE CITED 21

From 1934 to 1942 the Lake States Forest Experiment Station operated 10 large lysimeters at the Upper Mississippi Valley Soil Conservation Experiment Station, La Crosse, Wis. For several reasons, the results have not previously been written up. This is the first and final published report on the experiments.

The lysimeters were 20 feet long, 10 feet wide, and 4 feet deep. They were filled with undisturbed blocks of Fayette silt loam, a loess, plus an 8-inch layer of topsoil.

After a test period of about a year, treatments were established, and surface runoff, percolation, and soil loss were measured for 6 years. The treatments in six lysimeters were: hardwood seedlings with leaf mulch (two lysimeters), hardwood seedlings without leaf mulch, Scotch pine seedlings with needle mulch, grass, and annual grain. Results from the four other lysimeters are not given because of faulty percolation records.

Analysis of the data showed a strong interaction between treatment and season. Growing-season runoff from the mulched trees and grass was low compared with dormant-season runoff, whereas the reverse was true for the annual grain. The unmulched hardwoods were in between.

During the growing season, 6-year runoff averages for the mulched trees and grass ranged between 0.46 and 0.65 inch. In contrast, the unmulched hardwoods and the grain averaged 3.68 and 6.49 inches. Most of the runoff came from a few high-intensity storms. During the dormant season, the effect of treatment on runoff was much less pronounced, probably because of uneven accumulation of snow and frozen ground on the lysimeters.

Most of the percolation occurred during the dormant season. Only the [illegible] hardwoods yielded significant amounts (an average of 2.1 inches) during the growing season. Annual variation was high in both seasons. Treatment effects on dormant-season percolation were not clear-cut, for the same reasons as given for runoff.

Soil loss was very low from all the lysimeters that had a protective cover, and high from those with unmulched hardwoods and the grain. Most of this came from growing season rainstorms.

During the experiment the trees grew from rows of small seedlings to dense stands of saplings. Although the trend is not too clear-cut, growing season runoff appears to have decreased with time on all but the annual grain lysimeter.

Percolation from the mulched trees during the growing season showed a general decrease with time, but whether this is a real time trend or merely the result of climatic variations may be debatable.

The effect of time on soil loss from the unmulched hardwoods lysimeter was more pronounced. It dropped from 17.1 to 0.2 tons per acre in 5 years. The other lysimeters showed no change with time.

A separate analysis of individual periods of percolation showed that almost all the percolation occurred in the spring months, the result of melting snow and spring rains on wet soil. Percolate flowed for as long as 20 days without rainfall.

Analysis of the water budget showed that evapotranspiration accounted for about three-fourths of the precipitation. The figures agree well with other lysimeter studies made at the same location, and with estimates made for Madison, Wis. Total water yield from the lysimeters compared favorably with streamflow records from a nearby watershed.

INTRODUCTION

For 8 years, beginning in June 1934, the Lake States Forest Experiment Station operated 10 large lysimeters at the Upper Mississippi Valley Soil Conservation Experiment Station near La Crosse, Wis. Three lysimeters were seeded to native hardwood species and one was planted to Scotch pine seedlings. The other six were planted to grass or field crops or were given special, nonvegetative treatments. The first 2 years were used to test the uniformity of percolation, and to establish treatments. Treatment comparisons began with the third year and were continued for 6 years.

Sometime during the experiment, the percolation pipes from six of the lysimeters broke, invalidating, for the most part, the percolation records from those lysimeters. Since the percolation pipes were buried under about 5 feet of soil, the breaks were neither perceived nor investigated until after the experiment had ended and when, in Bates' words, "analysis of the data showed some impossible relations."

Fortunately, the tree-covered lysimeters, all four of which were on the west end of the installation, functioned properly, and the runoff and soil loss records for the other six were not affected by the malfunctioning of the percolation systems. One of the broken pipes, from a lysimeter with annual crops, had just a slight leak; Bates stated, "Do not believe (leak) caused either loss or gain." Although its percolation record may be slightly suspect, it has been used along with the "good" records.

This paper is the first and final report on the study. Because of the broken pipes and the premature ending of the experiment with the outbreak of World War II, the study yielded less information than was originally expected. Even so, the results are still pertinent — perhaps more so today than they would have been 10 or 20 years ago. The question of how much water is used and how much is made available for water supply by different kinds of crops is still a long way from being completely answered. The knowledge gained from this study should be a useful contribution toward this end.

THE AREA AND STUDY OBJECTIVES

The study site has been well described by Hays et al. (1949).[1] It is in the Driftless Area, an unglaciated region of some 10 million acres, mostly in Wisconsin, but also extending across the Mississippi River into the southeastern corner of Minnesota and into northeastern Iowa and down into Illinois. By some mysterious quirk of nature, the continental glaciers bypassed this area, leaving it a dissected plain, now weathered into an intricate drainage pattern. Flat or gently rounded ridges are a peculiarity of the landscape. Forests, predominantly oak-hickory, occupy only the very steep hillsides between the cultivated uplands and lowlands.

The lysimeters were located near the top of a windswept ridge. The ridgetop soils are loessal silt loams mapped either as Fayette or Dubuque. Colloidal content is low, but they are productive agricultural soils, and this has led to extensive overuse. Cultivation of slopes steeper than 30 percent is not uncommon.

Annual precipitation is about 32 inches. Two-thirds of this falls from May through September, much of it as high-intensity, convection storms. The ground normally freezes every winter, sometimes to a depth of 4 feet or more on openland, and this often contributes to spring floods. These things, combined with the land-use pattern and the erosive loess soils, have made the Driftless Area a land of flash floods and spectacular erosion.

From previous studies, Bates (1930) and Bates and Zeasman (1936) had found that there was practically no surface runoff on well-forested slopes. The lysimeter experiments were planned to find out how much of the infiltrated water was likely to become available as ground water, springflow, or streamflow, and how the water budget and soil loss differed for forest and nonforest crops.

[1] *Names and dates in parentheses refer to Literature Cited, pages 21 to 24.*

At the time the experiment was begun, lysimeters had not been used extensively in this country. One notable exception was a series of 12 lysimeters operated at Cornell University (Lyon et al. 1918 and 1930). However, most of the literature was from European experience and was applicable only in a very general way. An extensive review of these earlier experiments has been given by Kohnke et al. (1940).

Three other installations of large lysimeters, also constructed during the 1930's, have since become well-known. The monolith weighing lysimeters at Coshocton, Ohio, have been the subject of many papers. A recent progress report by Harrold and Dreibelbis (1958) gives the 10-year records from 1944-55. This report also contains a thorough review of lysimeter literature from 1939 to 1955. Colman and Hamilton (1947), in a two-part publication, described construction of the San Dimas, Calif., lysimeters and the relative performance of four different sizes. More recently, Sinclair and Patric (1959) reported on the operation of these lysimeters and gave results of some of the treatments. Compared to bare soil, all vegetation markedly decreased surface runoff and correspondingly increased infiltration. Evapotranspiration from vegetated soils was two or three times greater than from bare soil. Grass-covered soils yielded the most percolate.

Patric reported further on the large San Dimas lysimeters (1961a) and in another publication (1961b) assessed their value as a tool in forestry research. He concluded that lysimeters are a poor place for raising trees because the root systems are confined, and that, therefore, lysimeter results are at best only relative.

Zinke (1959), who also worked with the San Dimas large lysimeters, studied comparative moisture depletions under *Pinus coulteri* and under barren conditions. He reported that loss rates were nearly the same at various soil depths in the pine lysimeter, but that they diminished with depth in the bare lysimeter.

Construction and performance of the "Base Rock" lysimeters at the Sierra Ancha Experimental Forest were given by Martin and Rich (1948). Later, Rich also reported on further results (1959). He said that surface runoff and erosion increased as grass densities decreased, and that winter yield of percolate appeared to be independent of vegetation densities.

Other classic works on lysimetry are presented in the Symposium of Hannoversch-Munden (International Association of Scientific Hydrology 1959).

Good discussions of the various types of lysimeters and the limitations of each are given in the papers cited above by Harrold and Dreibelbis, and by Colman and Hamilton. The latter also discussed the presence of a "perched water table" in confined lysimeters and suggested design features to eliminate this unnatural condition. The recommendations were based on earlier studies by Neal et al. (1937) and by Richards et al. (1939), and on a later laboratory study by Colman (1946).

Other works that relate to this paper are cited at appropriate places in the text.

THE LYSIMETERS

Construction

Construction of the lysimeters and the installation itself have been fully described by Scholz and Stoeckeler (1940). However, the more important points are repeated here for convenience.

The completed installation consisted of 10 lysimeters, each 10 by 20 feet, or about 1/200 of an acre. They were 4 feet deep and were on a 10-percent slope that faced N. 79° E. Walls and floors were of reinforced concrete. They were built in pairs, each pair having a common wall. This was 6 inches thick and had a trough-shaped top to dispose of rain that fell on it. The pairs were separated from each other by a 3-foot strip which was later seeded to grass. Construction details are shown in figure 1.

The lysimeters were filled with natural profile blocks of the loessal Fayette silt loam. This is a well-drained, gray-brown podzolic soil commonly found on the ridges and upper slopes of the area.

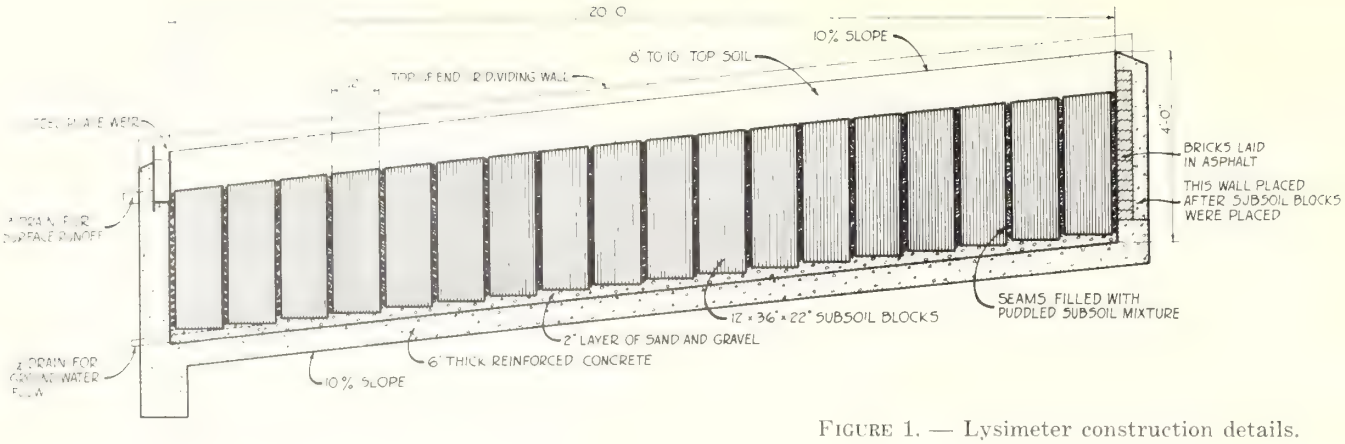
20 0
10% SLOPE
8 TO 10 TOP SOIL
TOP OF END OR DIVIDING WALL
STEEL PLATE WEIR
4 DRAIN FOR SURFACE RUNOFF
4 DRAIN FOR GROUND WATER FLOW
4'-0"
BRICKS LAID IN ASPHALT
THIS WALL PLACED AFTER SUBSOIL BLOCKS WERE PLACED
SEAMS FILLED WITH PUDDLED SUBSOIL MIXTURE
12 x 36" x 22" SUBSOIL BLOCKS
2" LAYER OF SAND AND GRAVEL
6" THICK REINFORCED CONCRETE
10% SLOPE

FIGURE 1. — Lysimeter construction details.

The undisturbed soil blocks or monoliths, which were 36 inches high, 22 inches wide, and 12 inches thick, were cut from a nearby borrow pit (fig. 2). They were cut out by means of special tools and were fitted into a steel casing for moving to the lysimeters. Since the uphill walls of the lysimeters had not yet been constructed, the blocks could be wheeled right into place. A block weighed about 500 pounds.

They were placed in the lysimeters in rows — 18 rows of 5 blocks each, or 90 per lysimeter. The blocks were spaced as uniformly as possible with about a 2-inch-wide space between them. These seams were filled with a viscous mixture of soil and water which was tamped in tightly. The blocks rested on a 2-inch layer of permeable sand and gravel so that percolated water would flow relatively unimpeded along the floor of the lysimeter to its outlet pipe.

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FIGURE 2. — How soil blocks of loess were cut from a natural profile.

After all the soil blocks were in place, the uphill walls were built. Later, an 8- to 10-inch layer of topsoil was distributed over the surface. Some time was allowed to elapse before putting on the topsoil. This was to permit "amalgamation" of the soil blocks with the material that had been tamped into the seams. During this interval, 8.4 inches of rain fell. Before applying the topsoil, the blocks were shaved off to a uniform level.

Operation

Surface runoff and percolation were measured by catching the amounts that came from each lysimeter in calibrated tanks that were located in a shed about 12 feet downslope. Small amounts were weighed. Three-inch pipes leading from a trough in the lower end of the lysimeter carried the surface water and soil, while smaller pipes that drained from the bottom of the lysimeter carried the percolate. The amount of soil in the runoff solution was determined by drying and weighing samples of the solution. At first, runoff volumes were corrected for soil content, but when the differences were found to be small this was discontinued.

In June 1936, a tipping bucket system was installed as an additional means of measuring both runoff and percolate. This system, which was hooked up to a 20-pen Bristol recorder, provided a continuous chart record automatically.

Precipitation was measured by a Ferguson recording gage placed near the installation. The gage was fitted with a Nipher-type shield to minimize errors in gage catch that result from wind movement.

Pretreatment Testing of Lysimeters

After the topsoil had been spread on the lysimeters, contour ridges were built, spaced at about 32-inch intervals (fig. 3). This was done to prevent runoff and erosion while treatments were being started and to test the uniformity of percolation.

The testing procedures were somewhat involved. The results were inconclusive, and the inferences drawn from them were somewhat conflicting, depending upon the period of time that was considered. Unequal distribution of snow apparently caused most of the difficulty.

According to Bates' unfinished report:

> The plan for the first year was to give percolation capacities a severe test, surface runoff being precluded by the ridges or terraces that had been formed in the soil . . . measurements were begun by drawing off the percolate into cubic foot buckets . . . the time required to fill a bucket was recorded.
>
> The data clearly show that there existed differences in the freedom with which water could be delivered. The same general characteristics were exhibited by the several lysimeters throughout the whole period of measurements.

Bates then went on to say that these differences in the discharge rates did not necessarily imply differences in amounts.

Scholz and Stoeckeler (1940) state:

> A preliminary check of the performance of the 10 lysimeters as judged by the amount of percolation water obtained over a period of 9 months revealed that the average percolate from the lysimeters was 148.8 cubic feet, with the maximum variation from the average amounting to only 3.7 percent. This very close check would indicate that the grout-filled seams offer no serious obstacle to obtaining results which are strictly comparable.

An unpublished manuscript by Scholz and Bates says:[2]

> . . . direct percolate from rain (June, 1934, to February, 1935) shows a very satisfactory degree of uniformity in the behavior of the lysimeters. . . . The considerable variability in total percolation is plainly related to the spring or snow-melting period of 1935, and this in turn to observed variations in the depth of the snow mantle. . . .

Percolation for various periods during the first year is shown in table 1. Data are given only for the lysimeters to be reported on here. Although there was some variation between lysimeters for individual periods, the totals for non-snowmelt periods agreed very closely. Total rainfall for the three periods was 35 inches. Values for the snow-

[2] *Scholz, Harold F., and Bates, Carlos G. The use of water by trees, grass, and crops in southwestern Wisconsin, and resultant residues for groundwater replenishment. Unpublished report on file at the La Crosse field office of the Lake States Forest Expt. Sta. 1939.*

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FIGURE 3. — Completed lysimeters before treatment. The terraces were built to prevent runoff and soil loss during the first year of seedling growth, and to test the uniformity of percolation. The lysimeters have a 10-percent slope to the right.

TABLE 1. — *Percolation during pretreatment period*
(Inches of water)

Condition and period	Lysimeter number and subsequent treatment				
	1. Mulched hardwoods	2. Unmulched hardwoods	3. Mulched pine	4. Mulched hardwoods	9. Annual grain
	PERCOLATION FROM RAIN				
Before topsoil added:					
June-August 1934	1.86	1.70	1.72	1.68	1.58
Topsoil terraced:					
Sept.-December 1934	7.31	7.25	7.67	7.62	7.26
April-May 1935	1.74	1.40	1.38	1.47	1.72
Total	10.91	10.35	10.77	10.77	10.56
	PERCOLATION FROM SNOWMELT				
Topsoil terraced:					
January-March 1935	.69	1.61	5.18	4.28	1.33

melt period differed widely because of uneven snow cover, so they are shown separately.

It would appear from the data that if snowpack differences are accounted for, the lysimeters can be considered alike with respect to percolation amounts. Pretreatment tests on surface runoff were not made. Apparently it was felt that if percolation were uniform, surface runoff would also be uniform. This is a logical assumption, since if the soil masses responded uniformly, surface runoff would be affected only by surface condition, and except for treatment effects, this was the same on all lysimeters.

The Treatments

In July 1934, when the lysimeters were still terraced, seeds of red and white oak (*Quercus rubra* and *Quercus alba*) and black walnut (*Juglans nigra*) were planted in lysimeters 1, 2, and 4. The following May, the terraces were leveled and 1-0 Scotch pine (*Pinus sylvestris*) seedlings were planted in lysimeter No. 3. Both seeds and seedlings were planted just a few inches apart in rows spaced at only 16 inches. This spacing permitted 15 rows of trees per lysimeter. The hardwood species were planted in blocks of 5 rows for each species. The upper 5 rows were white oak; the middle 5, red oak; and the lower 5, black walnut. The close spacing was used so that the trees would fully occupy the site in as short a time as possible. Throughout the experiment the trees were thinned when they began to crowd each other. The thinnings were chopped up and scattered over the respective plots.

The lysimeters not planted to trees were seeded to rye to prevent excessive erosion, since the plan was to allow the trees to grow for a year before treating the other lysimeters.

The experimental period actually began in the spring of 1936. At that time two of the hardwood plots[3] (1 and 4) and the pine plot were covered with a 2- to 3-inch layer of leaf litter. Hardwood leaves were used on the hardwood plots and Scotch pine needles on the pine plot to simulate natural conditions. The third hardwood plot was left unmulched. The litter was replaced as needed to keep the cover uniform throughout the study.

The reason for the mulched plots was this: The people who planned the experiments knew that forests influence the disposition of rainfall in many different ways; that one of these was by protecting the soil against raindrop impact and by insulating it against radiation; and that this was due largely to the layer of leaf litter or mulch that blankets the floor of a forest. So by having both mulched and unmulched plots, they hoped to be able to isolate the effect of this factor from the separate effects of the trees themselves. They

[3] *"Plot" as used here is synonymous with lysimeter.*

apparently felt that the effect of hardwood vs. softwood litter would not differ enough to justify separate experiments with each. So the mulched versus unmulched comparison was limited to the hardwoods. However, the interception effect of the two kinds of litter was investigated in a supplementary study.

Of the other two lysimeters whose records are used in this report, one was devoted to annual grain crops (barley 4 years, corn 2 years) and the other to grass. The grain was planted and harvested in the usual way. The grass was a heavy stand of Kentucky bluegrass (*Poa pratensis*), established by sodding. It was allowed to grow uninterrupted for the first 4 years, but starting with May 1939, it was clipped to simulate grazing use. The percolation records for this plot were faulty, so only its surface runoff and soil loss will be given. These records are included to give a comparative picture of how trees, grass, and cultivated crops may affect runoff and erosion in the study area.

LIMITATIONS OF THE STUDY

The results of any lysimeter study should be appraised in the light of the inherent weaknesses of lysimeters in duplicating truly natural conditions. Many of these, such as soil variability, border effects, and unnatural confinement of root systems, have been documented by various authors in the Symposium of Hannoversch-Munden (International Association of Scientific Hydrology 1959). Elsewhere Harrold and Dreibelbis (1958) reported that variation in percolation among lysimeters on the same soil type was due largely to soil heterogeneity and, in a small degree, to differences in the agricultural crop cover. They also discussed the probability of errors in measuring precipitation by standard methods and the effect that this has on computing the water balance from lysimeter data. Patric (1961b) discussed the inhibiting effect of root confinement on the growth of trees.

Certain limitations peculiar to the lysimeters of this study should be noted. Snow did not build up uniformly on the separate lysimeters. The tree-planted lysimeters tended to accumulate more snow by drifting than actually fell. Attempts to overcome this uneven distribution of snow by using snow fences and planting hedges were largely unsuccessful; drifting occurred through the years of the experiment. Snow depth was systematically measured, however, and these measurements are presented to help explain the erratic dormant-season results.

The paired construction and the short distance between pairs did not allow for isolation areas around individual treatments. This would have affected the later records more than the earlier ones because a marked difference in the height of the trees on the different lysimeters began to show up about the fourth year. By the end of the experiment (sixth year), the pines on lysimeter No. 3 were twice as tall as the unmulched hardwoods on adjacent lysimeter No. 2. This probably changed the effective area of these lysimeters (King et al. 1956). This may also have affected net rainfall on individual lysimeters.

No runoff records were lost by accident over the 6-year post-treatment period. However, it was suggested by Bates that inclined rains tended to fall on and drip from the lysimeter walls (which protruded about 6 inches above the soil surface) and thus form flow channels within the lysimeter during heavy rains. This could have produced slightly more runoff than would have occurred in a natural setting.

A perched water table in lysimeters and its restricting effect on percolation was suggested by Aderkas (1930) and was the subject of later research by Neal et al. (1937), Colman (1946), and Colman and Hamilton (1947). To see if this condition existed on the La Crosse lysimeters, soil moisture was sampled once during the study. The results showed that soil water apparently moved through the lysimeter soil mass much as it would move through a natural soil profile, except perhaps for some small effect at the seams between soil blocks.

Only one treatment — mulched hardwoods — was replicated. Apparently the original researchers felt that the pretreatment testing showed the lysimeters to be enough alike before treatment that replication was unnecessary. However, to strengthen treatment comparisons, the values for both replications of mulched hardwoods are given throughout the report.

ANALYSIS OF RECORDS

The results are summarized by hydrologic seasons rather than by years. Seasonal comparisons are more meaningful because rainfall effects are separated from snowmelt and frozen ground effects. This helps to reduce experimental error caused by climatic variations from year to year.

For purposes of analysis, May 1 was selected as the beginning of the water year. This approximates the ending of the dormant season, when soil moisture is usually at or near field capacity. The assumed growing season was May through October; and the assumed dormant season, November through April. Another reason for selecting May-April as the water year was that this made 6 full years of record available for analysis, the last records being taken in April 1942.

Effect of Treatment and Time

Treatment on only two (grass and annual grain) of the six lysimeters remained relatively fixed in time. The cover on the grain lysimeter, of course, varied with the annual planting, growth, and harvest cycle; and this probably accounted for some of the year-to-year differences in the water relations on this lysimeter. The occurrence of runoff-producing storms with respect to stage of crop development would have been particularly important.

The tree-covered lysimeters underwent a gradual change with time as the trees developed from rows of small seedlings to dense stands of saplings (fig. 4). With growth of the stems, the tree roots undoubtedly occupied more of the soil mass each year. An additional change probably took place on the unmulched hardwoods plot. Although there is

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FIGURE 4. — Tree growth on the lysimeters. Mulched hardwoods on the left, Scotch pine on the right. Upper picture, 1936; lower 1939.

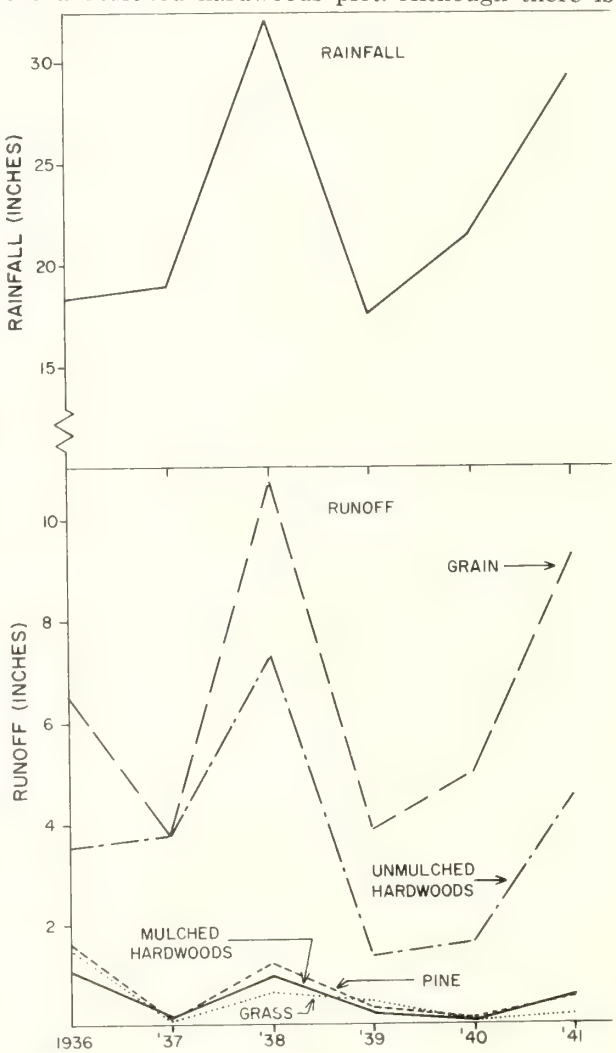

FIGURE 5. — Annual growing-season rainfall and runoff.

no record of it, natural leaf fall probably covered more of the soil each year. Cut-up thinnings were also scattered over the plot twice during the study.

Because of the changes on the lysimeters with time, the effect of treatment on soil and water relations also changed with time. Thus it is difficult to separate one from the other in an overall analysis. Showing monthly, seasonal, and annual values in the tables helps to do this to some extent. Six-year averages are also given. One should remember, however, that the average values by treatment reflect differences that are caused by both treatment and time. Where significant changes occurred with time, these are discussed separately.

On Runoff

Growing season. — During the growing season, the mulched hardwoods, the pine, and the grass yielded little runoff (fig. 5). Six-year averages were 0.46 inch for grass; 0.49 and 0.50 inch for the mulched hardwoods; and 0.65 inch for the mulched Scotch pine. In contrast, the unmulched hardwoods and the grain, both of which offered less protection to the soil, averaged 3.68 and 6.49 inches respectively. The effectiveness of forest litter in reducing runoff has been shown by a number of investigators.[4]

[4] *Bates and Zeasman 1930; Loudermilk 1930; Rowe and Colman 1951; Rowe 1955.*

TABLE 2. — *Runoff from major rainstorms, 1936-1941*

Storm date	Precipitation			Runoff					
	Amount	Intensity		Mulched hardwoods		Unmulched hardwoods	Pine	Grass	Annual Grain
		5 min.	30 min.	Lys. No. 1	Lys. No. 4				
	Inches	In./hr.	In./hr.	Inches	Inches	Inches	Inches	Inches	Inches
1936									
May 22	1.78	4.80	0	0.32	0.51	0.75	0.38	0.41	0.95
Aug. 27	1.73	2.36	1.40	.05	.05	.12	.03	.18	1.34
Sept. 15	2.37	1.80	1.30	.19	.16	.37	.13	.12	.75
Oct. 3	1.31	3.36	1.78	.17	.18	.62	.11	.02	.80
Total	7.19			.73	.90	1.86	.65	.73	3.84
1937									
June 19	2.27	5.10	3.52	.16	.12	1.60	.14	.06	1.54
Aug. 3	1.35	3.60	2.12	0	0	.64	0	0	.81
Aug. 18	1.34	3.22	1.54	.01	.01	.50	0	0	.66
Nov. 7	1.52	2.28	.95	.03	.04	.59	.02	0	.60
Total	6.48			.20	.17	3.33	.16	.06	3.61
1938									
July 2	1.02	2.39	1.64	0	.02	.42	.01	0	.65
July 5	1.55	3.31	2.00	.06	.07	.76	.09	.04	1.26
July 21	1.75	6.08	2.86	.03	.04	.82	.12	0	.75
Aug. 16	3.45	1.27	1.06	.47	.35	1.46	.59	.28	2.53
Sept. 5	2.10	1.84	.97	.04	.06	.65	.06	.02	.91
Sept. 9	1.99	3.24	1.82	.38	.33	1.00	.30	.27	.95
Total	11.86			.98	.87	5.11	1.17	.61	7.05
1939									
Aug. 20	6.05	2.48	1.34	.21	.18	1.35	.30	.42	3.09
1940									
June 7	2.37	4.04	2.52	0	.02	.58	.08	.01	1.47
Aug. 1	1.27	3.25	1.95	0	0	.11	0	0	.62
Aug. 16	1.53	5.85	3.08	0	0	.67	0	0	1.16
Aug. 24	1.49	2.02	1.40	0	0	.17	.01	0	.39
Total	6.66			0	.02	1.53	.09	.01	3.64
1941									
May 15	1.61	5.20	1.78	.04	.01	.57	.03	.01	1.08
June 29	1.03	4.50	1.90	0	0	.25	0	0	.52
July 17	1.51	3.27	2.12	.04	0	.46	.06	0	.79
Sept. 7	3.20	1.68	1.02	0	0	.59	.05	0	1.17
Sept. 15	2.63	4.32	2.24	.31	.39	1.36	.18	.08	1.87
Oct. 6	1.78	3.24	1.38	.10	.11	.63	.04	.02	.91
Total	11.76			.49	.51	3.86	.36	.11	6.34

TABLE 3. — *Total runoff from major storms as percent of total storm precipitation*

Year	Mulched hardwoods		Unmulched hardwoods	Pine	Grass	Annual grain
	Lys. No. 1	Lys. No. 4				
1936	10.1	12.5	25.9	9.0	11.4	53.4
1937	3.1	2.6	51.4	2.5	.9	55.7
1938	8.3	7.3	43.1	9.9	5.1	59.4
1939	3.5	3.0	22.3	5.0	6.9	51.1
1940	0	.3	23.0	1.4	.1	54.6
1941	4.2	4.3	32.8	3.1	.9	53.9
All years	5.2	5.3	34.1	5.5	4.1	55.1

Most of the yearly growing-season runoff came from just a few high-intensity storms (table 2). An average of four storms per year produced 71 percent of the runoff, using the annual grain plot as a base. This compares favorably with the findings of Hays et al. (1949). These storms made up only 36 percent of the total growing-season precipitation. To cite an extreme year, the 6.05-inch storm of August 1939 produced 81 percent of the runoff for that season from the annual grain lysimeter. The high runoff of 1938 and 1941 (fig. 5) is clearly related to the comparatively large number of major runoff-producing storms of those years (table 2).

Comparative runoff from the different vegetative covers expressed as a percent of storm rainfall may be of interest (table 3). The 6-year average was low for all mulched tree plots and for the grass (from 4.1 percent for the grass to 5.5 percent for the pine). On the other hand, the unmulched hardwoods gave up 34.1 percent and the grain 55.1 percent.

TABLE 4. — *Annual runoff as percent of runoff from annual grain lysimeter*

Year	Mulched hardwoods		Unmulched hardwoods	Pine	Grass
	Lys. No. 1	Lys. No. 4			
GROWING SEASON					
1936	15.2	18.2	54.5	24.7	23.5
1937	4.5	3.4	100.0	3.7	1.6
1938	9.6	8.8	68.3	11.2	5.7
1939	5.6	4.8	35.9	8.0	11.0
1940	0	.4	32.4	2.0	.3
1941	5.7	5.9	48.7	6.0	1.3
DORMANT SEASON					
1936-37	61.0	74.0	299.7	31.0	171.3
1937-38	90.6	67.1	183.7	80.1	65.4
1938-39	112.4	164.0	303.6	53.2	57.1
1939-40	237.5	171.6	432.8	26.5	61.5
1940-41	14.4	51.6	17.9	30.8	44.2
1941-42	1.7	17.1	9.7	19.7	53.7

Although the trend of growing-season runoff with time is not too clear-cut, it appears to have decreased over the years on all but the annual grain lysimeter (tables 4 and 5, fig. 6). This can best be seen by comparing the record with that of the annual grain lysimeter on which the vegetation influence did not change progressively with time (table 4, fig. 6).

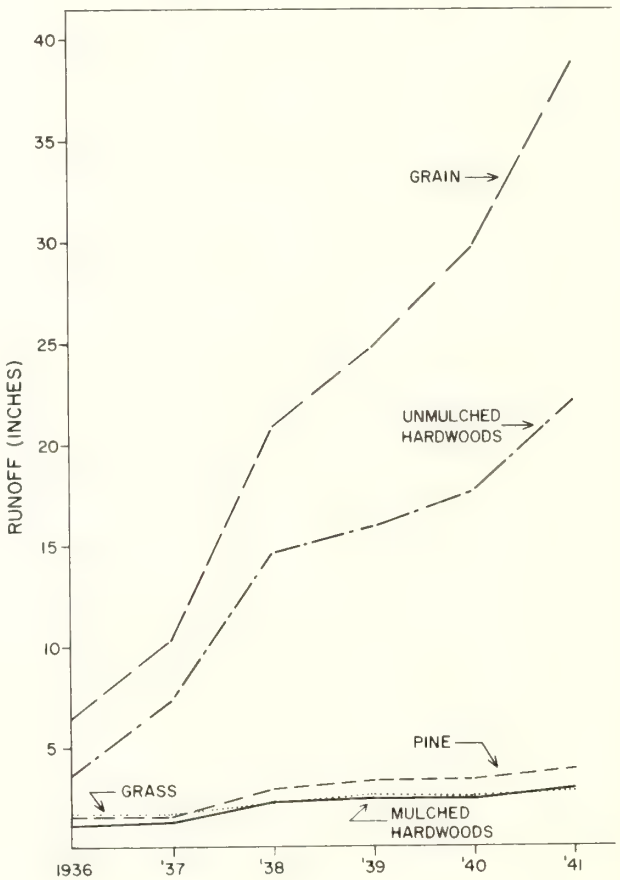

FIGURE 6. — Accumulated growing-season runoff.

TABLE 5. — *Seasonal precipitation, runoff, and percolation by years*
(Precipitation in inches; Runoff and percolation in percent of precipitation)

Year	Precipitation	Mulched hardwoods				Unmulched hardwoods		Pine		Grass [1]	Annual grain	
		Lys. No. 1		Lys. No. 4								
		Runoff	Percol.	Runoff	Percol.	Runoff	Percol.	Runoff	Percol.	Runoff	Runoff	Percol.
						GROWING SEASON						
1936	18.43	5.3	7.6	6.4	6.4	19.1	0	8.7	1.6	8.3	35.1	0
1937	18.93	.9	20.6	.7	17.5	19.9	0	.7	4.5	.3	19.9	0
1938	32.05	3.2	19.1	2.9	18.7	22.7	1.8	3.7	.9	1.9	33.3	0
1939	17.51	1.2	.3	1.0	.1	7.8	0	1.7	0	2.1	21.8	0
1940	21.42	0	.2	.1	0	7.5	.5	.5	0	.1	23.1	0
1941	29.19	1.8	7.1	1.9	5.8	15.4	6.7	1.9	0	.4	31.7	1.4
Av.	22.92	2.1	9.2	2.2	8.1	16.0	1.5	2.9	1.2	2.2	27.5	0.2
						DORMANT SEASON						
1936-37	8.03	9.6	51.2	11.6	52.3	47.0	0	4.9	51.0	26.9	15.7	0
1937-38	11.06	30.0	5.0	22.2	7.7	60.9	0	26.6	0	21.7	33.1	0
1938-39	9.62	22.1	31.6	32.3	33.6	59.7	25.1	10.5	37.4	11.2	19.7	0
1939-40	7.27	41.0	0	29.6	0	74.7	0	4.6	0	10.6	17.2	0
1940-41	10.39	7.6	34.8	27.1	1.9	9.4	59.5	16.1	0	23.2	52.4	.6
1941-42	8.34	.7	97.6	7.4	54.6	4.2	89.3	8.5	1.4	23.3	43.4	24.6
Av.	9.12	18.5	36.7	21.7	25.0	42.6	29.0	11.9	15.0	19.5	30.2	4.2

[1] Percolation record was faulty.

Dormant season. — The effect of treatment on dormant-season runoff, which was largely from melting snow, was less pronounced (table 6), probably because frozen ground is the major cause of dormant-season runoff (Hays et al. 1949). Most of the runoff normally occurs over a few days' time late in winter or in early spring when the accumulated snowpack melts. Rains at this time of the year can also contribute to it (Garstka 1944). Although forest cover is known to inhibit soil freezing in the study area (Scholz 1938), it is unlikely that the small trees and litter on the lysimeters would have begun to exert the same influence as do natural forest stands. These were essentially garden plots on soil that had been farmed for many years. The effect of living and dead plant materials on the ground, which exerted the primary influence on growing-season infiltration, was probably almost completely nullified when the ground froze. Although frost was not measured on the lysimeters, present-day knowledge of ground freezing (Pierce et al. 1958; Trimble et al. 1958; Sartz 1957) and the climate of the area both suggest that some freezing did occur on the lysimeters regardless of treatment.

TABLE 6. — *Dormant-season runoff by years*
(Inches)

Year	Mulched hardwoods		Unmulched hardwoods	Pine	Grass	Annual grain
	Lys. No. 1	Lys. No. 4				
1936-37	0.769	0.932	3.776	0.391	2.158	1.260
1937-38	3.322	2.460	6.736	2.937	2.397	3.666
1938-39	2.126	3.103	5.744	1.006	1.081	1.892
1939-40	2.978	2.152	5.429	.332	.771	1.254
1940-41	.787	2.814	.974	1.676	2.410	5.450
1941-42	.062	.620	.350	.713	1.942	3.616
Total	10.044	12.081	23.009	7.055	10.759	17.138
Average	1.67	2.01	3.83	1.18	1.79	2.86

TABLE 7. — *Snow depths on day of peak snowpack*
(Inches)

Date	Mulched hardwoods		Unmulched hardwoods	Pine	Grass	Annual grain
	Lys. No. 1	Lys. No. 4				
1-31-37	12.7	11.8	14.3	13.6	11.9	10.6
1-31-38	7.8	9.1	12.4	12.4	8.8	2.6
2- 7-39	4.0	9.7	12.6	19.4	3.4	2.6
3-14-40	14.2	8.4	22.7	13.9	3.7	5.0
3-12-41	15.4	7.6	24.6	10.3	6.4	8.5
1-17-42	14.2	5.6	18.4	4.3	3.1	10.0
Average	11.5	8.7	17.5	12.3	6.2	6.6

Another factor that influenced dormant-season runoff was the uneven distribution of snow. Table 7 shows average snow depth (water equivalent was not measured) on each lysimeter at the peak date each year. This should be a reasonable estimate of the relative amount of snow water available for runoff and percolation, even though snow depth at the peak date was not necessarily an indication of snow water at the time of melt.

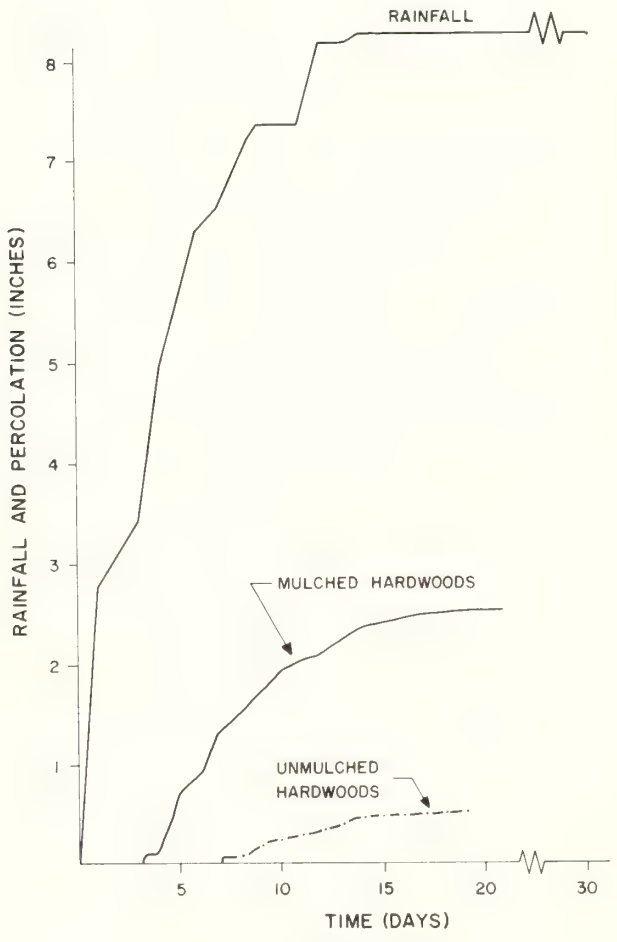

FIGURE 7. — Accumulated rainfall and percolation from prolonged summer rains, September 1938. Pine and grain plots showed no percolation during the month.

The impact of soil freezing and snowpack differences make it difficult to draw definite conclusions from the dormant-season data. While a deeper snowpack may have made more water available for runoff, it also may have had a greater inhibiting effect on soil freezing. Depth of snow is known to have a significant effect on soil freezing (Atkinson and Bay 1940; Bay et al. 1952). Thus less runoff could have come from the deeper snow because a shallower or less continuous frost allowed more water to infiltrate the soil.

The effect of a litter cover (the mulched trees and grass) as compared with bare ground (unmulched hardwoods and grain) may be reflected in the 6-year averages shown in table 6. However, the interrelationship between snow cover, vegetation and litter cover, soil freezing, and runoff is complicated. So the results of this phase of the experiment cannot be considered conclusive.

Annual distribution. — Seasonal runoff as a percent of annual runoff for the 6-year period is shown below:

	Percent of annual runoff during—	
	Growing season	*Dormant season*
Mulched hardwoods:		
Lysimeter No. 1	22.7	77.3
Lysimeter No. 4	19.9	80.1
Unmulched hardwoods	49.0	51.0
Pine	35.5	64.5
Grass	20.4	79.6
Annual grain	69.4	30.6

Growing-season runoff from the mulched trees and grass was low compared with dormant-season runoff, whereas the reverse was true for the grain. This probably reflects the influence of a ground cover in maintaining a high capacity for infiltration from rainstorms (Packer 1951), and also its lesser influence under winter conditions (Rich 1959). Runoff from the unmulched hardwoods was about evenly divided between the growing and dormant seasons.

On Percolation

Growing season. — Monthly and annual percolate during the growing season is given in table 8. Data for the grass-covered plot are not shown because the records were faulty. Only the two mulched hardwood plots yielded significant amounts, averaging 2.26 and 2.03 inches annually. There was marked variation by year. The pine lysimeter, for example, yielded percolate only during the first 3 years; the grain, only in the last year.

Percolation from the mulched trees during the growing season generally decreased with time (table 5). Whether this is a real time trend or merely the result of climatic variations may be debatable. Seasonal variation in rainfall, snow accumulation, and soil moisture can easily obscure differences in percolation that may be caused by differences in land use (Dreibelbis 1954). However, according to both theory (Penman 1956; Tanner 1957) and experimental evidence (Moyle and Zahner 1954; Metz and Douglass 1959; Hill 1961), as a plant cover becomes denser and as its root system more fully occupies the soil, it will invariably use more water. This may well explain the apparent trends that the lysimeter records show.

Rate of percolate flow varied widely by treatment during an extended period of rain in September 1938 (fig. 7). Even after more than 8 inches of rain, the unmulched hardwoods lysimeter yielded but little percolate, the pine and grain, none.

The difference in percolation between the mulched hardwoods and the mulched pine is interesting. According to the pre-treatment test period, summer percolation from the three lysimeters was very much alike (table 1). Surface runoff in September 1938 was also similar, differing by less than one-tenth of an inch. Still the hardwoods yielded about 2.5 inches of percolate for this month as compared with none from the pine. The difference was probably caused by one or more of the following: higher transpiration loss by the pine; higher evaporation loss through the pine litter than through the hardwood litter; higher interception loss from the pine.

The low percolate yield from the unmulched hardwoods and grain is probably best explained by the higher amounts of surface runoff, hence a drier soil mass and greater opportunity for moisture storage in these lysimeters. The unmulched hardwoods and grain plots yielded 7.3 and 10.7 inches of surface runoff during the 1938 growing season, while the three mulched plots yielded only about 1 inch.

Dormant season. — Treatment effects on dormant-season percolation are not clear-cut. Annual variation was great (table 9) and does not appear to be related to snow depths (table 7). Dormant-season percolation can be affected by many different factors: soil moisture deficit at the end of the growing season; dormant-season runoff; snow drifting; net insolation, and snow interception; the pattern of soil freezing; and spring rains. The effects of treatment are therefore highly speculative. There does appear to be a gross relationship between snow depth and total water yield, however. Average percolation plus runoff from snowmelt (table 10) correlated well with peak snow depth for the three hardwood and the grain lysimeters (fig. 8) but not for the pine plot.

Percolation from the unmulched hardwoods increased substantially in the last 2 years (table 9). Part of this was no doubt the result of more favorable conditions for percolation in those years. This is indicated by the record from the grain lysimeter. However, it could also result from a combination of decreased surface runoff (table 5) and lower transpiration loss (as compared with the mulched hardwoods and pine) as well as from its deeper snowpack (table 7). In contrast to the unmulched hardwoods, the pine lysimeter yielded no percolate at all in 1940-41, and only 0.12 inch during the high percolation year of 1941-42. This was a decided drop from the first 3 years, when it yielded about the same amounts as the mulched hardwoods. The change probably resulted from increased soil moisture withdrawal by the faster-growing denser pines.

On Soil Loss

Soil loss was very low from all lysimeters that had a protective mulch cover but high from the

TABLE 8. — *Growing-season rainfall and percolation by months and years*
(Inches)

Year and month	Rainfall	Mulched hardwoods		Unmulched hardwoods	Pine	Annual grain
		Lys. No. 1	Lys. No. 4			
1936						
May	3.17	0.682	0.537	0	0.051	0
June	2.24	.711	.637	0	.239	0
July	0.91	0	0	0	0	0
August	3.65	0	0	0	0	0
September	5.24	0	0	0	0	0
October	3.22	0	0	0	0	0
Total	18.43	1.393	1.174	0	.290	0
1937						
May	3.46	2.983	2.809	0	.836	0
June	4.42	.920	.507	0	.018	0
July	0.76	0	0	0	0	0
August	4.33	0	0	0	0	0
September	2.22	0	0	0	0	0
October	3.74	0	0	0	0	0
Total	18.93	3.903	3.316	0	.854	0
1938						
May	4.95	3.251	3.299	.058	.300	0
June	4.52	.116	.123	.022	0	0
July	7.52	.303	.076	0	0	0
August	5.51	.027	0	0	0	0
September	8.21	2.431	2.494	.493	0	0
October	1.34	0	0	0	0	0
Total	32.05	6.128	5.992	.573	.300	0
1939						
May	2.13	0.060	0.021	0	0	0
June	2.32	0	0	0	0	0
July	1.71	0	0	0	0	0
August	8.54	0	0	0	0	0
September	0.89	0	0	0	0	0
October	1.92	0	0	0	0	0
Total	17.51	.060	.021	0	0	0
1940						
May	3.41	0	0	0	0	0
June	5.45	.036	0	.116	0	0
July	2.06	0	0	0	0	0
August	7.29	0	0	0	0	0
September	0.38	0	0	0	0	0
October	2.83	0	0	0	0	0
Total	21.42	.036	0	.116	0	0
1941						
May	6.10	.979	.548	.408	0	0
June	5.29	1.044	.841	1.167	0	.395
July	2.17	0	0	0	0	0
August	1.01	0	0	0	0	0
September	9.28	0	0	0	0	0
October	5.34	.045	.310	.370	0	0
Total	29.19	2.068	1.699	1.945	0	.395
Total	137.53	13.588	12.202	2.634	1.444	.395
6-year av.	22.92	2.26	2.03	.44	.24	.07

TABLE 9. — *Dormant season percolation by years*
(Inches)

Year	Mulched hardwoods		Unmulched hardwoods	Pine	Annual grain
	Lys. No. 1	Lys. No. 4			
1936-37	4.111	4.203	0	4.099	0
1937-38	.550	.852	0	0	0
1938-39	3.043	3.233	2.413	3.595	0
1939-40	0	0	0	0	0
1940-41	3.611	0.195	6.184	0	.058
1941-42	8.143	4.552	7.450	.118	2.053
Total	19.458	13.035	16.047	7.812	2.111
Average	3.24	2.17	2.67	1.30	.35

TABLE 10. — *Percolation plus runoff during snowmelt period*
(Inches)

Year	Mulched hardwoods		Unmulched hardwoods	Pine	Annual grain
	Lys. No. 1	Lys. No. 4			
1936-37	3.82	4.29	3.36	4.19	1.17
1937-38	3.30	3.22	5.41	2.92	1.92
1938-39	3.85	4.82	6.28	4.60	1.89
1939-40	2.98	2.15	5.43	0.33	1.25
1940-41	4.40	3.01	6.83	1.64	4.99
1941-42	5.59	3.45	6.15	0.83	5.02
Average	4.07	3.49	5.58	2.42	2.71

TABLE 11. — *Annual[1] soil loss*
(Tons per acre)

Year	Mulched hardwoods		Unmulched hardwoods	Pine	Grass	Annual grain
	Lys. No. 1	Lys. No. 4				
1936-37	0.15	0.19	17.09	0.12	1.08	11.15
1937-38	.03	.06	2.45	.01	.01	15.71
1938-39	.03	.10	0.39	.02	.03	55.80
1939-40	.04	.01	.13	.01	.01	5.46
1940-41	0	0	.21	.01	.02	12.20
Average	.05	.07	4.05	.03	.23	20.06

[1/] From May 1 to April 30. Soil loss was not measured after September 30, 1941.

unmulched hardwoods, particularly the first year, and the grain (table 11). That forest litter and dense ground cover minimize soil loss, even though surface runoff may occur, has been shown by many others (Bates and Zeasman 1930; U.S. Forest Serv. and U.S. Soil Conserv. Serv. 1940; Marston 1952).

The 5-year averages of 0.03 to 0.07 tons per acre for the mulched trees versus 0.23 tons per acre for the grass is not a meaningful comparison. The

higher average for the grass results from the 1.08 tons per acre for 1936-37; 97 percent of this came from one storm in May, just a few weeks after the sod had been laid. The higher-than-average values for the mulched trees in 1936 also resulted from this storm. The litter had been spread on the plots about the time that the sod had been laid, and the loosely lying leaves and needles were undoubtedly less effective in reducing erosion than they were later.

Although the effect of time on runoff and percolation was somewhat uncertain, its effect on soil loss from the unmulched hardwoods was clear-cut. Soil loss dropped from 17.09 tons per acre the first year to 0.21 tons per acre the fifth year. The decrease was progressive, despite the fact that the erosion potential, as judged from the performance of the annual grain lysimeter, varied greatly from year to year. The other plots showed no change with time. Since the soil was almost fully protected from the start (except for a settling period the first month), soil loss was minimal throughout the study.

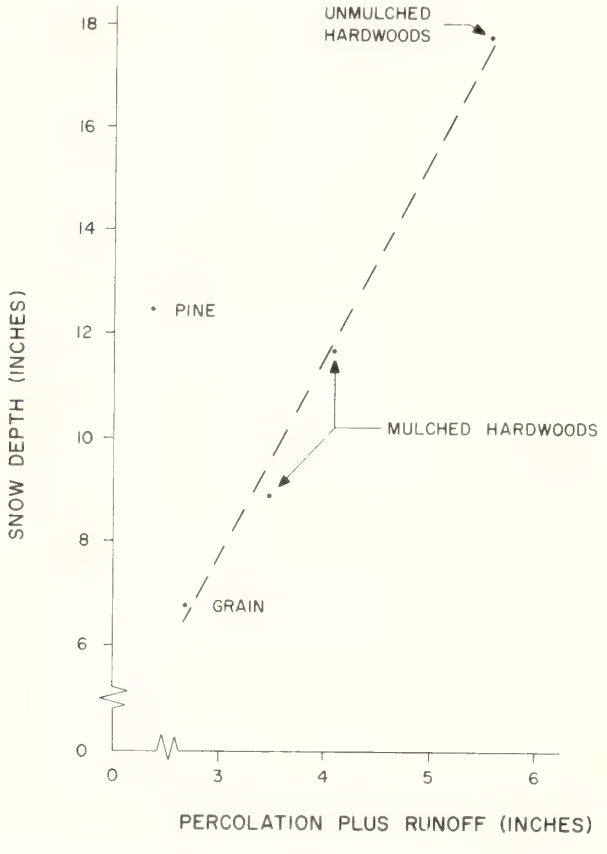

FIGURE 8. — Relationship of average percolation plus runoff during snowmelt period to peak snow depth.

Seasonal distribution of soil loss did not follow that of runoff. Whereas most of the runoff occurred in the dormant season, most of the soil loss occurred in the growing season. This was expected, since dormant-season runoff was largely from frozen soil, and rate of soil detachment is normally low under this condition.

Distribution and Duration of Percolation

In the average year, percolate flowed on relatively few days, even from the higher producing lysimeters (table 12). This was especially true during the growing season. Most of the percolation that did occur then came in May and June. In most years there was a continuous flow from April into May, and some years it continued into June. This reflected the high level of soil moisture that is normal here in early spring months. Only in 1938 did any percolate flow in summer months, and this was an especially wet summer (table 13). Low percolate yield and ground-water flow during the months of high evapotranspiration loss are typical of the climatic belt, as has been shown by other lysimeter investigations (Lyon and Bizzell 1918; Harrold and Dreibelbis 1958), by streamflow records, and by recent studies of springflow on the Coulee Experimental Forest.[5]

Most of the dormant-season percolation occurred in March and April, the result of melting snow and spring rains on wet soil. The curves for each year except 1939-40 (none occurred on any of the lysimeters during the dormant season that year) are given in figure 9. Normally, fall rains went into soil moisture storage, replenishing moisture that had been depleted during the summer months. There were a few exceptions to this, however, one of which is worth noting. Percolate had flowed from the three hardwood lysimeters in September 1938, following an 8-inch rain. A 3-inch rain in November, falling on the already wet soil, also produced flow from these lysimeters (fig. 10).

There was only limited opportunity during the years of the experiment to study soil water depletion from percolation during extended rainless periods. Percolation occurred a few times, however, when precipitation either was lacking, was very low, or fell only as snow. Daily percolate

[5] *Data on file at La Crosse, Wis., field office of the Lake States Forest Experiment Station.*

TABLE 12. — *Number of days in which percolate flowed*

Year	Mulched hardwoods		Unmulched hardwoods	Pine	Annual grain
	Lys. No. 1	Lys. No. 4			
			GROWING SEASON		
1936	48	44	0	26	0
1937	47	42	0	36	0
1938	68	59	31	13	0
1939	9	4	0	0	0
1940	4	0	4	0	0
1941	38	32	41	0	8
Average	36	30	13	12	1
			DORMANT SEASON		
1936-37	108	79	0	109	0
1937-38	17	14	0	1	0
1938-39	108	107	83	39	0
1939-40	0	0	0	0	0
1940-41	37	13	54	0	7
1941-42	87	81	83	19	44
Average	60	49	37	28	8

yields during these periods are plotted in figure 10 to show the rate of drainage of soil water from the lysimeters when evapotranspiration losses were low. Percolate flowed continuously for as long as 20 days without rainfall. That water can be discharged from unsaturated soils over extended periods of time has been verified recently by Nixon and Lawless (1960), and by Hewlett (1961), who gave this as one explanation for the base flow of streams.

TABLE 13. — *Precipitation by months and seasons (Inches)*

Month and season	1936	1937	1938	1939	1940	1941
			GROWING SEASON			
May	3.17	3.46	4.95	2.13	3.41	6.10
June	2.24	4.42	4.52	2.32	5.45	5.29
July	0.91	0.76	7.52	1.71	2.06	2.17
August	3.65	4.33	5.51	8.54	7.29	1.01
September	5.24	2.22	8.21	0.89	0.38	9.28
October	3.22	3.74	1.34	1.92	2.83	5.34
Total	18.43	18.93	32.05	17.51	21.42	29.19
			DORMANT SEASON			
November	0.66	2.27	3.25	0.26	2.97	1.70
December	1.10	0.45	0.84	0.76	1.35	1.63
January	1.69	0.81	1.28	0.57	1.26	0.23
February	1.01	0.92	1.65	0.71	0.58	0.70
March	0.34	2.79	0.55	1.25	1.70	2.69
April	3.23	3.82	2.05	3.72	2.53	1.39
Total	8.03	11.06	9.62	7.27	10.39	8.34
Water year	26.46	29.99	41.67	24.78	31.81	37.53

The Annual Water Budget

The complete water budget is shown in table 14. The budget is given for two 3-year periods because of tree growth and its apparent effect on evapotranspiration. The grass plot is not shown because of its faulty percolation record, but a rough estimate is given a little farther on.

Evapotranspiration rates were high for all crops, ranging from 65 percent of precipitation (unmulched hardwoods in the first 3-year period) to 96 percent (pine in the second 3-year period). Similar high rates of evapotranspiration were reported from lysimeter studies in Ohio by Harrold and Dreibelbis (1958) and from another lysimeter study at the La Crosse Station by Kilmer et al. (1944). From heat-budget measurements and lysimeter data, Tanner[6] estimated average annual net radiation at Madison to be 29 inches and evapotranspiration (average for all cover conditions) to be 24 inches. These are estimates of the long-term

[6] *Tanner, C. B., unpublished data, College of Agriculture, University of Wisconsin.*

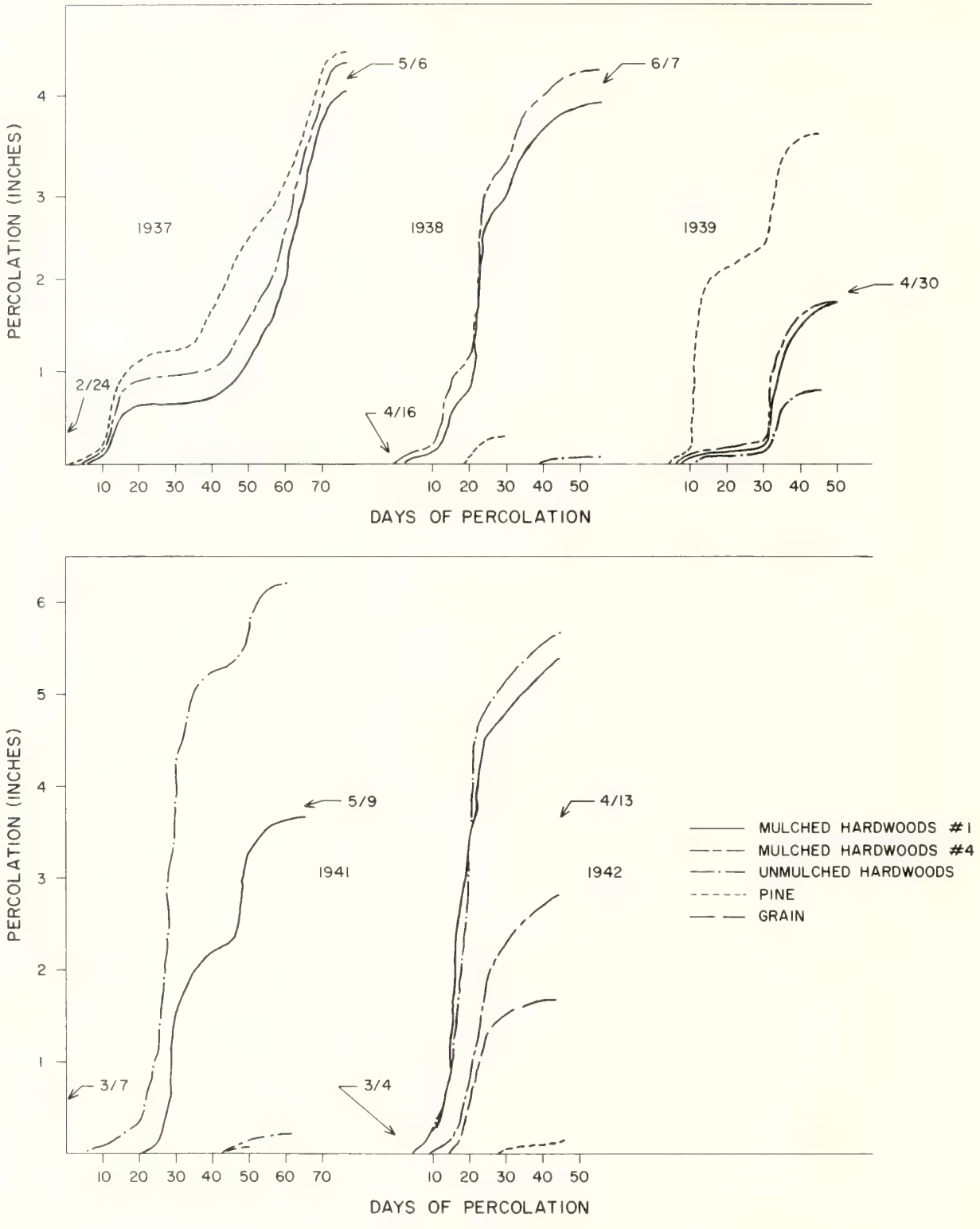

FIGURE 9. — Accumulated percolation from snowmelt and spring rains, 1937-39, 1941, and 1942. No percolation occurred during this period in 1940.

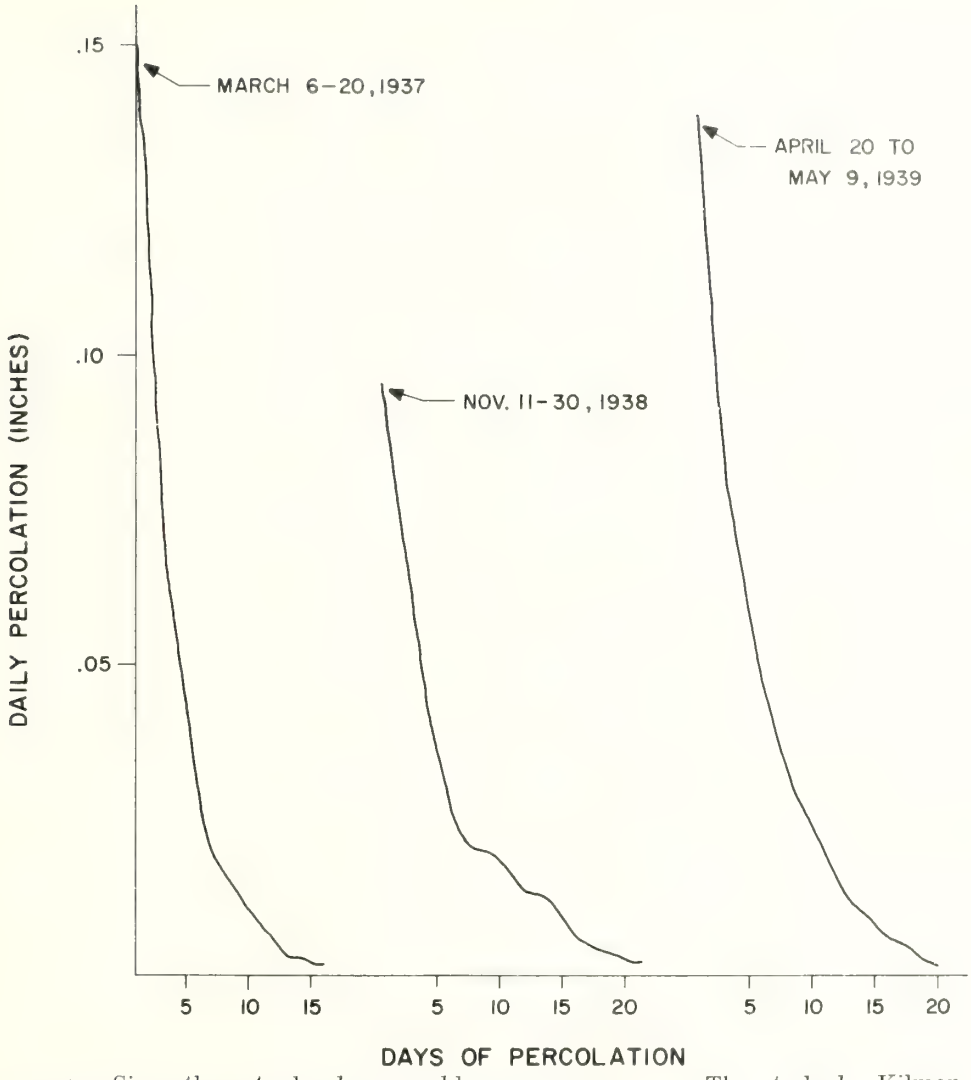

Figure 10. Rate of soil moisture drainage during rainless periods, lysimeter No. 1 (mulched hardwoods).

averages. Since the actual values would vary somewhat from year to year as precipitation does, the figures are not directly comparable to the data cited here.

In terms of total water yield, the unmulched hardwoods and the grain produced the most — about 10 inches. This resulted from their high rates of surface runoff, hence less opportunity for loss by evapotranspiration.

At the time the Forest Service lysimeters used in this study were built, the Soil Conservation service installed a battery of six soil-monolith lysimeters. These were only 36 inches in diameter, but soil type and depth were the same as those of the Forest Service lysimeters. The surface of the lysimeters was level. They were located on the same slope and were less than 50 feet away.

The study by Kilmer et al. (1944), which was made on the Soil Conservation Service lysimeters, provides an interesting comparison for the water budget from the annual grain lysimeter, since both were operated from 1936 to 1938. Three lysimeters of Kilmer's study were in corn annually. The water budget for the two follows (in inches):

	Annual grain Forest Serv.	Corn SCS
Runoff	9.2	12.8
Infiltration	23.5	21.8
Percolation	0	.2
Evapotranspiration	23.5	21.6

Estimates for a low, closely growing cover obtained by Bay and Hull (1952) may serve as a substitute for data lost from the grass lysimeter.

TABLE 14. — *Average annual water budget for two 3-year periods*[1]
(Inches)

Treatment	Precipitation	Runoff	Infiltration[2/]	Percolation	Evapo-transpiration	Total yield
			1936-1938			
Mulched hardwoods						
Lysimeter No. 1	32.71	2.30	29.91	6.38	23.53	9.18
Lysimeter No. 4	32.71	2.91	29.80	6.26	23.54	9.17
Unmulched hardwoods	32.71	10.28	22.43	1.00	21.43	11.28
Pine	32.71	2.42	30.29	3.05	27.24	5.47
Annual grain	32.71	9.24	23.47	0	23.47	9.24
			1939-1941			
Mulched hardwoods						
Lysimeter No. 1	31.37	1.52	29.85	4.64	25.21	6.16
Lysimeter No. 4	31.37	2.11	29.26	2.16	27.10	4.27
Unmulched hardwoods	31.37	.74	26.63	5.23	21.40	9.97
Pine	31.37	1.23	30.14	.04	30.10	1.27
Annual grain	31.37	9.45	21.92	.84	21.08	10.29

[1/] Water year: May 1 to April 30.
[2/] Precipitation less runoff. Interception ignored.

They studied water losses from clover-timothy hay on the Soil Conservation Service lysimeters at La Crosse for 2 years — 1943 and 1945. Average annual losses and the 2-year averages, all in inches, were:

	1943	1945	Average
Precipitation	24.41	38.73	31.57
Runoff	2.82	4.72	3.77
Infiltration	21.59	34.01	27.80
Percolation	.48	4.24	2.36
Evapotranspiration	21.11	29.77	25.44

Although the range between the 2 years is large, average precipitation is about the same as for the period 1939 to 1941. So the corresponding evapotranspiration of 25.44 inches should be a rough approximation of what evapotranspiration losses from the grass lysimeter would have been for this period.

It is interesting to compare lysimeter records with local streamflow records (Harrold 1947). Coon Creek, a 77-square-mile watershed south of La Crosse, provides such a comparison. About 35 percent of the watershed is forested; most of the rest is in agricultural crops or pasture. Soils on about three-fourths of the watershed are loessal silt loams — the soil used in the lysimeters. For the 1936 to 1938 period used in this report, the flow of Coon Creek was 7.05 inches. This was 25 percent of the average precipitation measured on the watershed. Total yield from the lysimeters for this period ranged from 17 to 34 percent of precipitation.

EVALUATION OF THE STUDY

The results of this lysimeter study, though limited in time and statistical design, should still be of interest to land-use hydrologists and others concerned with the conservation of soil and water. Because analysis and publication were unavoidably delayed, the writeup is perhaps of more value in confirming the results of more recent research than it is in presenting new findings.

As originally planned, the study was to continue for a much longer period of time so that the "forest" plantings would have had greater opportunity to alter the soil. Comparing the small trees with agricultural crops, both on an agricultural soil, does not provide a true measure of the effects of trees in a forest. In many ways the study dealt more with a variety of agricultural crops. Under these conditions then, it would be presumptuous to draw inferences on the relative effects of forests versus agricultural crops on elements of the water cycle.

Uneven accumulation of snow and the lack of snow-water measurements on the lysimeters reduced the accuracy of the water budget figures. When accurate water budget figures are desired from lysimeter measurements in climates where snow is a significant component of the annual precipitation, provision should be made to prevent drifting or to properly account for it on the lysimeters.

Despite its shortcomings, the study provided some new information on the disposition of precipitation by different types of cover on loessal soils in a cold, midcontinental climate. And it further confirmed that the distribution, amount, and quality of water are strongly affected by the nature of the watershed cover and by the condition of the land.

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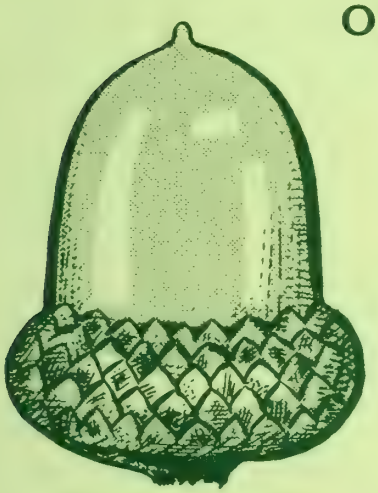
APRIL 1964

SEEDING and PLANTING TESTS of NORTHERN RED OAK in WISCONSIN



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Seeding and Planting Tests of Northern Red Oak in Wisconsin

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CONTENTS

INTRODUCTION 1

ESTABLISHMENT METHODS 1
- Direct Seedings 1
- Plantings of 1-0 and 2-0 Nursery Stock 1

INITIAL SUCCESS 2
- Direct Seedings 2
- Plantings of Nursery Stock 2

SURVIVAL AND GROWTH AFTER THE YEAR OF ESTABLISHMENT 3
- Effect of Competition 3
- Animal Damage 4

DISCUSSION 5

SUMMARY 7

INTRODUCTION

Much more must be learned about the silvicultural management of the mixed-oak forests of the Lake States region. This is particularly true when an overstory of northern red oak is to be replaced by a new crop of the same species.

Recent studies show that the small-block clear cut and the shelterwood system both hold promise for regenerating oak woodlands in Wisconsin.[1] [2] These preliminary tests indicate that enough seedlings of northern red oak (*Quercus rubra* L.) and other desirable hardwoods exist to restock the stand, *providing* they can force their way through a tangle of competing herbaceous plants and shrubs.

The final evaluation of these two cutting methods cannot be made for another 10 to 15 years. They may or may not provide adequate natural regeneration of the more desirable tree species. In the meantime, the possibility of obtaining northern red oak reproduction by artificial methods is being studied. This paper reports some early results of recent tests.

ESTABLISHMENT METHODS

Direct Seedings

Direct seeding is one way to keep northern red oak in the mixed hardwood forests of Wisconsin. Under certain conditions such seedings can be quite successful.

In order to test the feasibility of regenerating this species by planting acorns, 1,250 seed spots were established on a forest clearing in the spring of 1952. Of these seed spots, 500 were fenced against rabbits; 250 of them were also protected with cylindrical screens[3] to prevent squirrels, chipmunks, gophers, and mice from eating the acorns. The other 750 seed spots had no protection.

The test was made on the Hardies Creek Timber Harvest Forest. Three acorns were planted 1 to 2 inches deep in the mineral soil of each seed spot. This seed had been collected on the same Forest during the 1951 season and was stratified in sand over winter so that it would not dry out or freeze.

Plantings of 1-0 and 2-0 Nursery Stock

Only a portion of the acorns collected in 1951 was used for the direct-seeding tests the following spring. The balance of this stratified seed was sown in beds at the Hugo Sauer Nursery in Rhinelander, Wis. The resulting stock thus became available as 1-0 and 2-0 seedlings in 1953 and 1954 respectively.

Six hundred 1-0 trees, averaging 5.3 inches in total height, were planted in 1953 on a forest opening adjacent to the one where the direct seedings had been made a year earlier, and in 1954 two plots of 2-0 stock with an average total height of 9.5 inches[4] were also established on the Forest. One of these, involving 268 seedlings, was planted in a part of the stand that had been clear cut a few years earlier. The second one, comprising 306 trees, was planted on abandoned agricultural land. Both the 1-0 and 2-0 nursery stock were hand-planted, using mattocks and the hole method, in 18- by 18-inch scalps (fig. 1).

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[1] *Scholz, Harold F., and DeVriend, A. J. Natural regeneration on a 2-acre mixed-oak clear cutting 5 years after logging. U.S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 48, 11 pp., illus. 1957.*

[2] *Scholz, Harold F. Present status of oak management in Wisconsin. Iowa State Univ. Jour. Sci. 34: 649-660. 1960.*

[3] *Stoeckeler, J. H., and Scholz, H. F. A cylindrical screen for protecting direct seedings of forest tree species. Jour. Forestry 54: 183-184. 1956.*

[4] *These averages are based upon a 120-tree sample for 1-0 stock and a 116-tree sample for 2-0 stock.*

FIGURE 1. — Planting northern red oak seedlings with the mattock-and-hole method.

INITIAL SUCCESS

Direct Seedings

At the end of the first growing season, one or more northern red oak seedlings occupied 806 of the 1,000 seed spots that were open to possible depredations by rodents. If a minimum of one tree per spot is considered satisfactory stocking, the seeding was 81 percent successful. One or more small oak trees were also established on 237, or about 95 percent, of the spots screened against rodents.

Actually, the losses caused by animals were less than anticipated. In earlier tests on the same area, the success ratio for screened as compared to unscreened seed spots was about 1.6 to 1.0. The difference between the two treatments was substantially smaller in 1952, being in the ratio of about 1.2 to 1.0. Losses due to rodent depredations were small enough in both instances to raise a question as to whether screening costs can be justified in terms of the added benefits. However, such losses might be more serious on large-scale seedings, especially in years when acorns generally are in short supply. This point merits further study.

Plantings of Nursery Stock

There was no first-year mortality for either the 600 1-0 northern red oak seedlings planted in 1953 or the 574 2-0 trees planted in 1954. This does not mean that they all escaped damage, but merely that none were killed.

SURVIVAL AND GROWTH AFTER THE YEAR OF ESTABLISHMENT

The post-establishment mortality that occurred in the 1952, 1953, and 1954 seedings and plantings was primarily the result of competition from other vegetation or of animal damage. Except where corrective measures were taken, these factors also retarded the height growth of the young oak. Insect and disease losses were minor.

Effect of Competition

Northern red oak seedlings of natural origin frequently are killed or held back by overtopping herbaceous vegetation and woody shrubs.[5]

The seeding and planting tests in this study show that artificially regenerated oak is affected in the same way. Not only are some trees killed by too much shade, but also the height development of many others is restricted. The importance of shade is demonstrated as follows:

Each year from 1952 to 1959 the shrubs and herbaceous plants were cut ("weeded") to within 2 or 3 inches of the ground on the same alternate 5-row strips of the direct-seeded area. This treatment was also used on the open-forest sites that had been planted with 1-0 and 2-0 northern red oak nursery stock. Nothing was done to eliminate or modify the natural vegetative cover on the adjacent check areas.

When all of the trees were 10 years old from seed (at the end of the 1961 growing season) there was a clear indication that both survival and height growth were better on weeded than on unweeded strips (table 1). The data also show that 1-0 stock made better height growth but showed poorer survival than 2-0 stock. Some of these differences are very striking when viewed on the ground, but their statistical significance could not be determined because of the unreplicated character of the study.

The principal shrubs on the Hardies Creek Timber Harvest Forest area are gray dogwood (*Cornus racemosa* Lam.), raspberry (*Rubus strigosus* (Michx.) Maxim), blackberry (*R. allegheniensis* Porter), and prickly gooseberry (*Ribes cynosbati* L.). As long as there is

[5] *Scholz and DeVriend, 1957; see footnote 1. Also Scholz 1960, see footnote 2.*

TABLE 1. — *Survival and height growth of northern red oak in weeded and unweeded strips*

Character of planting and treatment	Survival of 1st yr. stocking after—		Average total height of all seedlings	
	5th yr. of age	10th yr. of age	5th yr. of age	10th yr. of age
	Percent	*Percent*	*Inches*	*Inches*
Direct seedings[1]				
Weeded trees (20 rows)	79	74	21	74
Unweeded trees (20 rows)	74	68	15	50
1-0 nursery stock[2]				
Weeded trees (10 rows)	88	84	28	100
Unweeded trees (10 rows)	80	56	14	63
2-0 nursery stock[3]				
Weeded trees (5 rows)	97	95	22	75
Unweeded trees (5 rows)	98	94	17	47

[1] *Total trees at the end of the first year (1952) were: weeded, 843; unweeded, 765*

[2] *Total trees at the end of the first year (1953) were: weeded, 200; unweeded, 200.*

[3] *Total trees at the end of the first year (1954) were: weeded, 129; unweeded, 139. These totals do not include the 2-0 trees that were planted on abandoned farmland.*

a sparse-to-moderate stocking of these "brush" species they do not seem to inhibit the development of forest regeneration too drastically. However, when any of them form dense colonies, the seedlings of northern red oak and other tree species find survival difficult.

There is no way of determining, at this time, whether the somewhat suppressed trees in the unweeded rows eventually will be overtopped by the more vigorous oak in the weeded strips. If this happens, it may be necessary to reassess the benefits of weeding in terms of growth potential as well as survival.

Blackberry probably offers the most dangerous competition to a young stand. In an unweeded, 5-row strip of the direct-seeded area, all except 11 percent of the northern red oak trees that were present in 1952 had disappeared by 1961 in one of these bramble patches. The survival was 67 percent of the first-year stocking in an adjacent weeded strip. The corresponding 1961 survival values for 1-0 nursery stock were 30 percent when the young trees had to compete with dense thickets of brush and 98 percent where such shrubs were controlled by annual weedings.

The old-field planting of 2-0 stock was characterized by excellent survival (95 percent 8 years after planting) but poor form (fig. 2) and rather disappointing height growth. Apparently, the small trees were inhibited by the heavy sod of bluegrass and weeds which occurs on this area. Whatever the cause, the 10-year-old oak (in 1961) averaged only 37 inches tall. The same lot of nursery stock did much better on an open-forest site. There it averaged 47 inches and 75 inches tall on unweeded and weeded strips, respectively (table 1). Additional study is needed to determine how form and growth rate in plantings of small oak can be improved on old fields and abandoned pastures.

Animal Damage

Data from the 10-year regeneration tests suggest that animal damage to small oak seedlings is cyclic. Most of it occurred during two winters, those of 1954-55 and 1955-56. Complete records of all injured and uninjured trees were kept during the latter year. A summary of these data shows that 67 percent of 1,379 trees under observation was damaged to some degree by rodents, deer, or mechanical factors (table 2).

FIGURE 2. — The 10-year-old northern red oak trees on this open, soddy, old-field site are characteristically limby and multiple-stemmed.

TABLE 2. — *Animal damage comparison in fenced and unfenced seed spots—winter of 1955-56*

Category	Area unfenced or fenced only to exclude deer (750 seed spots)		Area with rabbit-proof fence, excludes all animals except mice (500 seed spots)	
	No.	*Percent*	*No.*	*Percent*
Undamaged trees	130	19.3	321	45.6
Damaged trees:				
By rabbits only[1]	228	33.8		
By mice only[1]	158	23.4	379	53.8
By both mice and rabbits[1]	140	20.7		
By deer	3	[2] 0.4		
Non-animal (mechanical injury, disease, insects, etc.)	16	2.4	4	0.6
Total	675	100.0	704	100.0

[1] *There is no particular problem in identifying these two kinds of animal damage. Rabbits clip the twigs and stems with a clean, slanting cut, whereas mice girdle the bark and wood with a series of undulating bite-marks.*

[2] *Only 20 out of 30 rows of seed spots were subject to deer damage, but even on an adjusted basis it is very doubtful whether this kind of injury would exceed 1 percent.*

It is evident from table 2 that rabbit damage can be eliminated in new seedings and plantings of oak by the proper type of fence (fig. 3). However, there is some question whether this added expense can be justified in terms of ultimate benefits. True, rabbits killed some of the small oaks and slowed the growth of many more. However, of greater importance is the fact that most of the trees recovered quickly, though they were top-clipped, side-clipped, or even cut back to the ground.

The actual height difference between fenced and unfenced trees amounted to 16 inches at the end of 10 years (fig. 4). On the area subject to animal injury, the small trees averaged 54 inches tall. Where rabbits were kept out by a fine-mesh woven wire fence, the oak seedlings had an average total height of 70 inches. It is doubtful, though, that this extra margin of growth spells the difference between success and failure. For, by 1961, even on that part of the seeding subject to rabbit injury, 45 percent of the trees were 4.5 to 14.0 feet tall and another 33 percent were in the 2.0 to 4.5-foot range. While some of these juvenile oaks may be damaged further by animals or competing vegetation, it seems reasonably certain that the majority will survive.

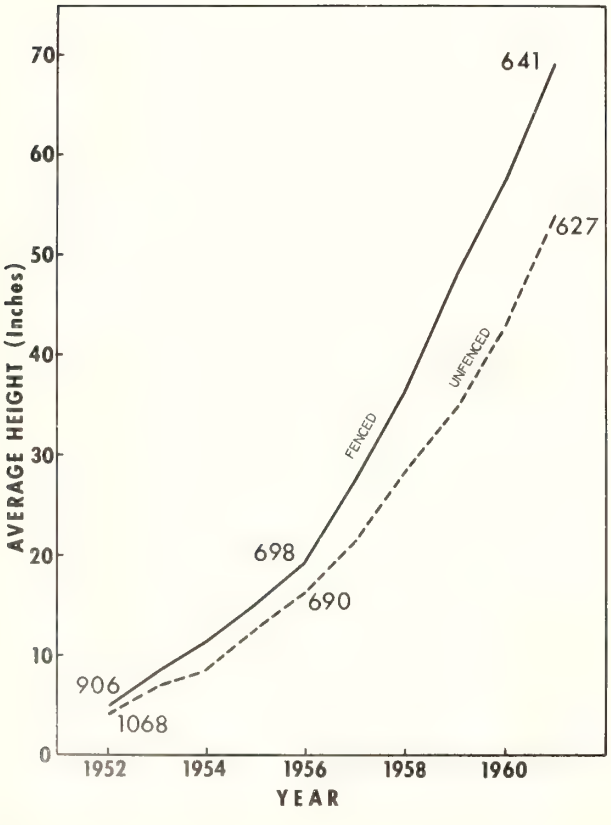
DISCUSSION

Preliminary field tests are encouraging, for they give considerable assurance that the mixed-oak forests in Wisconsin can be regenerated artificially with this valuable timber tree if the need arises. The choice of methods — direct seeding or planting nursery stock — will depend upon personal considerations, comparative costs, and the availability of nursery facilities, among other things.

Shrubs and herbaceous vegetation killed some of the young oaks in the test and retarded the height growth of many others. Yet, these losses were reduced and the average height growth was stimulated by the simple expedient of annual weedings which cut the competing plants back to within 2 or 3 inches of the ground.

While some problems were encountered

FIGURE 3. — The combination of fencing materials shown here protected a direct seeding of northern red oak from rabbits. It also kept out deer.



during these tests, in every case countermeasures could have been taken that would have assured a higher level of success. For example, squirrels, chipmunks, and mice destroyed the acorns in many seed spots. But these losses were virtually eliminated when the spots were protected with hardware-cloth cylinders.

Likewise, rabbits cut back the tops and lateral branches of many of the small northern red oak on areas that were not fenced. Mice girdled and side-clipped the twigs of other seedlings, but these tiny rodents can be controlled by trapping or poisoning. In a few cases, deer ate the tops of seedlings, but such damage, like that caused by rabbits can be eliminated by properly constructed fences.

FIGURE 4. — Rabbit damage comparison. Average height growth of fenced and unfenced northern red oak seedlings. Weeded and unweeded areas combined. The numbers along the trend lines indicate the number of living trees at the time of measurement.

When these various problems require further study, formal experiments can be designed to investigate them. In the meantime, the results obtained from the 10-year tests on the Hardies Creek Timber Harvest Forest will be helpful to the practicing forester in southern Wisconsin or elsewhere in the mixed-oak forest region. There is now fairly good assurance that northern red oak can be maintained as a key species in this hardwood complex. Natural regeneration is preferable, but if the need arises this particular oak can be kept in these stands by direct seedings or by planting 1-0 or 2-0 nursery stock.

SUMMARY

1. A series of regeneration tests, involving direct seedings of northern red oak and out-plantings of 1-0 and 2-0 nursery stock of the same species, is in progress on the Hardies Creek Timber Harvest Forest in southwestern Wisconsin.

2. There were some depredations of acorns by rodents in direct seedings. These losses were reduced somewhat by protecting the seed spots with hardware-cloth cylinders. Eighty-one percent of the unprotected spots were stocked with one or more seedlings at the end of the first growing season, compared to 95 percent for screened spots. There is, thus, a question whether the added benefits of using the screens are worth the extra cost.

3. Overtopping shrubs and herbaceous vegetation had an adverse effect upon seedlings and nursery stock. When this competing cover was cut back annually to within 2 or 3 inches of the ground, both the survival and total height of the released trees were better than on adjacent unweeded check strips.

4. During two out of nine winters, extensive damage was done to both seeded and planted northern red oak by rabbits and mice. Deer also nipped the tops of a few trees. While animal damage caused some mortality, its chief effect was to set the trees back for a year or two and reduce their average total height.

5. When all the factors of success and failure are evaluated, one must conclude from these 10-year artificial regeneration tests that it is perfectly feasible to maintain northern red oak in the mixed-oak forest type by direct seedings or by planting nursery stock, if natural regeneration proves inadequate.

SOME RECENT PAPERS
IN THE LAKE STATES STATION SERIES

Station Papers:

Proceedings of the Fifth Lake States Forest Tree Improvement Conference. Sta. Paper 98, 42 pp. 1962.

Three Growing Stock Density Experiments in Minnesota Red Pine — A Progress Report, by Robert E. Buckman. Sta. Paper 99, 10 pp., illus. 1962.

Identification of Conifer Insects by Type of Tree Injury, Lake States, by H. J. MacAloney and D. C. Schmiege. Sta. Paper 100, 41 pp., illus. 1962.

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RESEARCH PAPER LS-8
APRIL 1964

Recreational Use of the Quetico-Superior Area

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M. H. Dickerman, Director
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U. S. DEPARTMENT OF AGRICULTURE

FOREWORD

In 1960 the Lake States Forest Experiment Station initiated a program of forest recreation research. Currently three full-time Station staff members are doing research in this field.

The initial study dealt with use patterns and with user interests and characteristics in the Boundary Waters Canoe Area, which has been the subject of numerous basic questions concerning recreation policy. This publication by Dr. Lucas is the first major report of our forest recreation research program. Subsequent publications will deal with other phases of this study and will also report on recreation research by other staff members.

Your comments and suggestions concerning the utility of these studies will be helpful in guiding future research.

U. S. FOREST SERVICE
RESEARCH PAPER LS - 8
APRIL 1964

Recreational Use of the Quetico-Superior Area

Robert C. Lucas

LAKE STATES FOREST EXPERIMENT STATION
M. B. Dickerman, Director
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE

The Station is maintained in cooperation with the University of Minnesota.

Four abstract cards are included at the back of this report
for the reader's convenience.

Contents

Page No.

PARADOX OF WILDERNESS RECREATIONAL CAPACITY 1

THE SETTING 3
- Major Site Characteristics 3
  - Location and size 3
  - Physical geography 3
  - Land use 4
  - Management policies 5
- Major Situational Characteristics 7
  - Location relative to population centers and transportation routes 7
  - Location relative to other recreation areas 8

THE STUDY AREA AND PERIOD OF COVERAGE 8

METHODS OF DATA COLLECTION 10

AMOUNTS OF USE 11
- Visitor Totals 11
- Types of Recreation 11

DISTRIBUTION OF USE 13
- Use by Type of Accommodations 13
  - Paddling canoeist use 13
  - Motor canoeist use 14
  - Auto campground use 14
  - Boat camper use 14
  - Resort use 14
  - Private cabin use 15
  - One-day use 16
  - Auto sightseeing 16
- Use by Type of Water Travel 16
  - Canoe use 16
  - Motorboat use 16
  - Dominant use 16
  - Total use 16

FACTORS RELATED TO USE DISTRIBUTION 16
- Factors related to Use of Starting Points 19
  - Paddling canoeist use 19
  - Motor canoeist use 20
  - Auto campground use 33
  - Boat camping use 34
  - Resort use 35
  - Private cabin use 35
  - One-day use 35
  - Summary of factors related to use of starting points 36
- Factors Related to Use of Water Routes 36
  - Canoe use 36
  - Boat use 38
  - Summary of factors related to use of water routes 40

TRENDS IN RECREATIONAL USE 40
- Total Visits 41
- Use by Types of Recreationists 42
- Summary of Projections by Types of Use 46
- Use by Areas 47

SUMMARY AND CONCLUSION 48

LITERATURE CITED 49

PLATES (Color Maps) 21-32

THE PARADOX OF WILDERNESS RECREATIONAL CAPACITY

The Quetico-Superior area is the most widely known recreational region in the northern Great Lakes area. Its core consists of Quetico Provincial Park in Ontario and the Boundary Waters Canoe Area (formerly known as the Superior Roadless Area) of the Superior National Forest in Minnesota (Color Plate I on p. 21).

Its beautiful, peaceful lakes and forests have been the subject of more than 40 years of controversy. The center of this conflict has been the role of wilderness or primitive recreation in the development of the area. Neither Quetico Provincial Park nor the Boundary Waters Canoe Area is strictly defined by the administering agency as a wilderness area. Nevertheless, almost everyone thinks of these two areas as wilderness, at least in the general sense of Webster's meaning: "A tract or region uncultivated and uninhabited by human beings."

This clearly requires an absence of man and his works and poses the paradox of wilderness recreation: the more people visiting a wilderness area,[1] the less it is a wilderness. Mass recreation is possible, but mass solitude is not.

If a wilderness experience is considered socially desirable—and both the United States and Canada have clearly made this decision many times both inside and outside of the government—then the question arises as to the capacity of wilderness areas to provide this experience. Some compromise is obviously necessary between a complete wilderness with no use and the converse of very heavy use with no wilderness qualities left.

As the first essential step is understanding the problem of capacity, this report will describe recreational use and explain it as far as possible. Four aspects will be considered: the number of visitors, the types of visitors, the distribution of visitors over the area, all for 1961, and trends in use. Widely differing opinions have been expressed on all of these subjects during past controversies. This study will not eliminate controversy, but it should provide a better basis for discussion.

A second publication will attempt to relate these use patterns and trends to the capacity of the area for providing the wilderness experience for which it is intended. Questions such as the degree and extent of crowding and conflict between different types of use can only be considered after a description of use has laid the foundation.

The emphasis throughout is upon the Boundary Waters Canoe Area and its closely related fringe (Fig. 1). Necessary supporting data from Canada are introduced, but user interviews were not conducted in Canada and the degree of detail is less. The two parts of the Quetico-Superior are closely related as far as capacity is concerned; this will be true as long as the border can be easily crossed at several points. At the present time parts of the Boundary Waters Canoe Area serve as corridors to Canada for many people. If, in the future, capacity is reached (in the minds of the users) on one side of the boundary, an overflow may affect the other side.

Nevertheless, the emphasis on the American side seems necessary. Not only is capacity a more pressing problem in Minnesota but also there is more use and apparently more conflict between types of use and over policies. Furthermore, less is known about use in the Boundary Waters Canoe Area than in Quetico Park. Entry is completely uncontrolled in the Superior National Forest; there are no check points or travel permits as in Quetico Park. Also Quetico has only six official entrances, while the Boundary Waters Canoe Area has over 60 possible access points (about half with significant use potential), which makes estimating use much more difficult. For both areas estimates are available for recent years on total use but almost nothing on types of use or distribution.

[1] *As used in this study, "wilderness area" in lower case letters means any essentially undeveloped, relatively lightly used land. U. S. Forest Service land officially classified as Wilderness Areas (U-1) or Wild Areas (U-2) will always be capitalized. Quetico-Superior is used here in the narrow sense of Quetico Provincial Park and the Boundary Waters Canoe Area plus the immediate periphery, the waters of which serve as access routes. "The Canoe Country" is a synonym. Border lakes will be used for the larger area from Rainy Lake to Lake Superior (see Fig. 1). The Boundary Waters Canoe Area proper is sometimes referred to in this paper as the Canoe Area and is abbreviated to B.W.C.A. in tables.*

NOTE: *The author, Dr. Robert C. Lucas, is an Economic Geographer on the staff of the Lake States Forest Experiment Station. The Station is maintained at St. Paul 1, Minn., by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of Minnesota.*

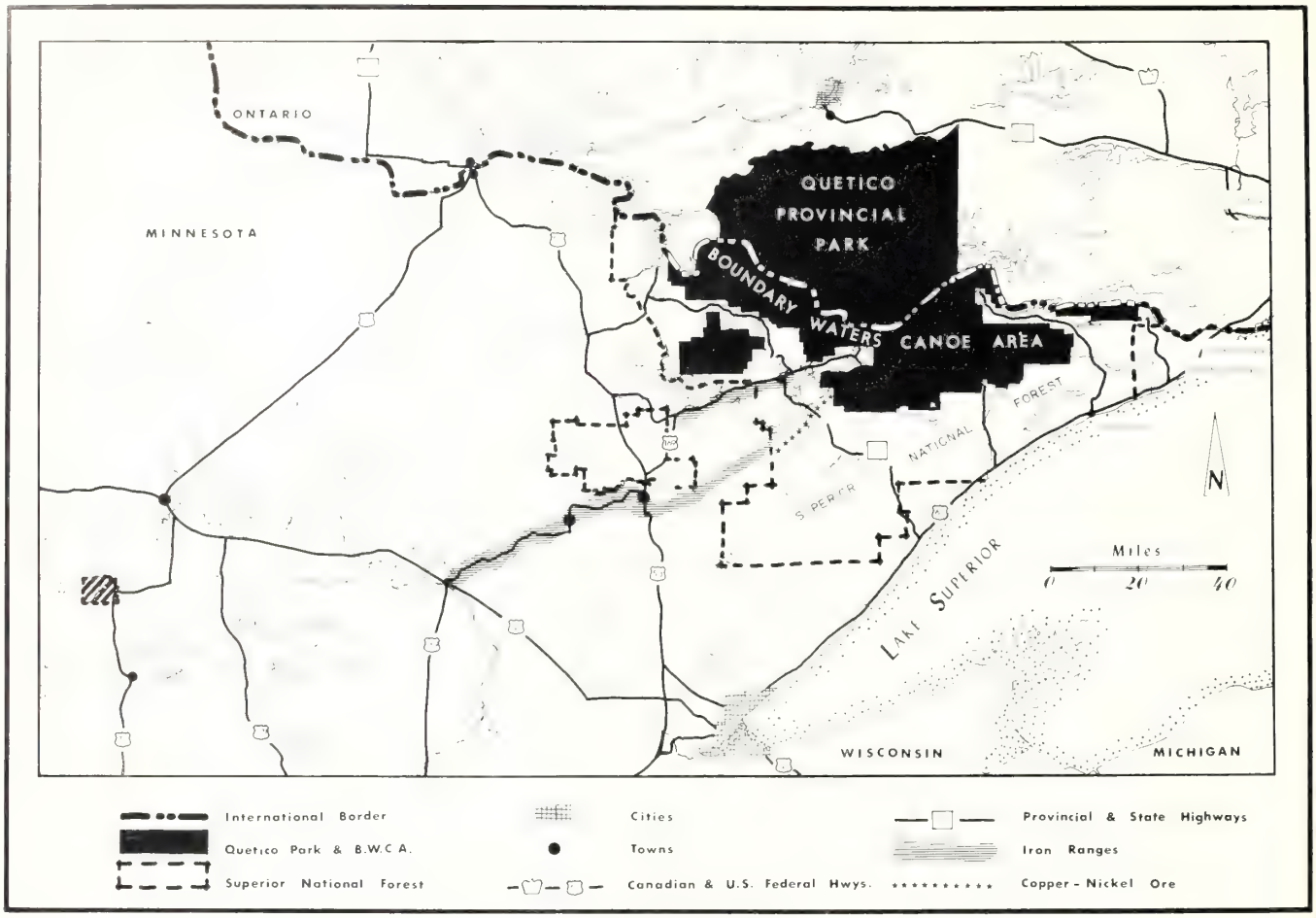

FIGURE 1. — The regional setting.

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FIGURE 2. — Lower Basswood Falls, on the Canadian border is one of the many beautiful falls which are scenic focal points.

Before the use of the Quetico-Superior area can be discussed, the internal or site characteristics and the external relations or situational qualities must be considered to help in understanding the attraction of the area and the influences on its use.

Major Site Characteristics

Location and Size

The Quetico-Superior area straddles the international boundary between the United States and Canada north of Duluth, Minn. (Fig. 1). It extends about 110 miles from east to west, and 60 miles from north to south. Quetico Park is compact, has regular, simple boundaries, and includes 1,132,800 acres. The Boundary Waters Canoe Area is divided into three separate parts. It is elongated, with complex section-line boundaries in most places, and includes 1,038,743 acres of land and water.

The two areas combined total 3,371 square miles, only about 60 square miles less than Yellowstone National Park and about 20 times the area of the Minnesota State Park System in 1961.

Physical Geography

1. *Land forms and drainage*

Lakes are the most essential physical feature related to recreation in the Quetico-Superior. The Boundary Waters Canoe Area is 16 percent water (Superior National Forest 1948, p. 3).[2] There are also many bogs. The streams are usually short and often are wild, white dashes from one dark lake to another (Fig. 2). This tangled drainage is the legacy of the continental glaciation. Old river channels were filled in and new basins were hollowed out or produced by the irregular deposition of glacial drift. Thousands of lakes formed in these new basins.

The shape and orientation of the lakes varies regionally. The most distinctive lake pattern occurs east of a line from Gunflint Lake to Brule Lake (see Plate I on p. 21 for these locations). Almost every lake here is long from east to west and narrow from north to south. Another region of somewhat less elongated lakes, trending northeast-southwest, extends from Ely northeast to Saganagons Lake in Canada. Most of the other lakes are essentially nonlinear or ink-blot shaped.

The Canoe Country varies in elevation from 1,100 to over 2,200 feet above sea level, but local relief is generally not great, although steep short slopes are common. Only about 250 feet separate the highest and lowest points on the U. S. Geological Survey's Ely Quadrangle. The "ridge and valley" section east of Gunflint Lake and Brule Lake has more relief; for example, south of Rose Lake a ridge rises steeply almost 400 feet.

The complex geology of the border lakes country is directly related to recreational use and even to capacity. The lakes and locally sharp relief, together with the forest vegetation, form the scenery, which is a major attraction (Fig. 3). The low relief makes possible the effective concealment of logged areas by leaving a shoreline screen of trees. Such concealment is usually not possible in the mountainous West. Lake size, frequency, orientation, and shape are all related to routes and frequency of contact between parties. The linear lakes usually provide direct and easy routes. The main "voyageur's highway" was over such linear lakes from Grand Portage west to Prairie Portage (into Basswood Lake). On the other hand, these elongated and narrow lakes tend to concentrate routes, almost ensuring that all other groups will be seen. In contrast, the nonlinear lakes with their complex shorelines and abundant islands provide more varied lines of travel and less frequent encounters with other parties within their labyrinths.

2. *Climate*

Relief from summer's heat is often stressed in northern Minnesota's advertising. The July average minimums in the Canoe Country are a pleasant 9 degrees lower than in Chicago, and 16 degrees cooler than in Kansas City—"good sleeping weather."

3. *Forest cover*

The towering red and white pines mentioned so often by admirers of the Quetico-Superior are not common, although a few large specimens here and there add immensely to the beauty of a lakeshore (Fig. 4). The forest today in the Boundary Waters Canoe Area, according to Superior National Forest records, is predominantly jack pine with spruce-fir and aspen following in that order. Only 3 percent of the area has red and white pine as the dominant cover.

This is no longer a virgin forest. The more accessible parts of the Boundary Waters Canoe Area (about one third) were logged between 1890 and 1920 (Superior National Forest 1948, p. 4) and were reforested by aspen and birch. These parts are heavily used for

[2] *Names and dates in parentheses refer to Literature Cited on page 49.*

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FIGURE 3. — This rock-rimmed lake with a forest made up largely of jack pine is typical of much of the Canoe Country.

recreation today because of the same accessibility; therefore, a great many visitors see primarily the less impressive deciduous forest. Due to greater inaccessibility, the early 20th century cutting in Quetico Park was less extensive, and as a result less of the Park is covered with aspen-birch forest.

4. *Animal life*

Big game is not abundant within the Canoe Country, but some species that are rare elsewhere in Minnesota are fairly common here. These animals, such as moose and timber wolves, lend a good deal of color to the country. The black bear is common. Deer are also present and seen quite often by travelers who do not use outboard motors. The loon is the Canoe Country's trade-mark.

Fish are rather sparse, but the more desired species —northern pike, walleyes, smallmouth bass, and lake trout—comprise most of the catch, rather than the panfish that are found in more fertile waters of the south.

Early summer recreation seems to be depressed by mosquitoes and flies, which are much more numerous and bothersome at that time than in late summer.

Land Use

One of the most striking characteristics of this large area is the lack of population and settlement features. The road network outside it unravels and ends near the boundaries. The few temporary logging roads are closed to general travel. No railroads are operating now, although old railroad grades exist. There are almost no permanent residents in either area. A small but decreasing number of resorts and summer homes still exist within the Boundary Waters Canoe Area (in 1963), but there are none in Quetico Park.

A second major feature of the area is its use for recreation. It is noted for a fairly rugged, demanding, "wilderness" type of canoe travel—demanding in both a mental and physical sense. The conventional, less demanding sorts of recreational use are also present—use by visitors from resorts, private cabins, and auto campgrounds outside the Boundary Waters Canoe Area and Quetico Park, who usually travel by motorboat.

All uses involving the production of commodities —logging, mining, and water power generation—are limited by policy, environment, or both.

Logging is the most important of the commodity uses. Two thirds of the National Forest land within the Boundary Waters Canoe Area is now subject to timber sales conducted under special restrictions (Superior National Forest 1948, pp. 14-15), and a number of areas, some quite large, are being harvested.[3] Log-

[3] *For a description of these restrictions and an evaluation of this policy see Lucas 1963.*

ging is also allowed in Quetico-Provincial Park,[4] although almost all the visitors, from the Minnesota side at least, think the Park is closed to cutting. The word "park" probably contributes much to this misconception.

There has been some very small-scale mining activity in Quetico Park and just outside the Boundary Waters Canoe Area, but there is none now. Low-grade copper-nickel ore along the South Kawishiwi River on the Canoe Country fringe (Fig. 1) has been prospected by International Nickel Company but not developed. Titaniferous magnetite in the eastern Canoe Area has also been prospected but left undeveloped.

There is no hydroelectric generation in the Quetico-Superior area now, but a small dam at Gabbro Lake (inside the Boundary Waters Canoe Area) stores water for a dam and generating station outside the Canoe Area. There are remnants of a number of other small crude dams left after logging started early in the 20th century. At least one dam in the Canoe Area has been rebuilt because the water level dependent on it had come to be considered "natural" through long control of the vegetation and navigation (Superior National Forest 1948, p. 17). Four lakes—Moose, Newfound, Sucker, and Birch—are made into one body of water by this dam at Prairie Portage, on the Canadian border.

Agriculture exists at only a handful of spots on the fringes of the area, and is fast disappearing.

[4] *Letter from A. B. Wheatley, Acting Chief, Parks Branch, Ontario Dept. of Lands and Forests, to C. R. Williams, Quetico Park Superintendent, dated Feb. 27, 1961.*

Management Policies

These unusual, almost anachronistic qualities exist only because of strong public policies. In the Boundary Waters Canoe Area the management policies are the result of action by the U. S. Forest Service, the Congress, the President, and the courts. The State of Minnesota has enacted similar legislation and has managed the State lands inside the Canoe Area to support Federal policies. Private individuals and groups have played an important role in developing the policies in both countries. The Province of Ontario is the only governmental authority controlling land in Quetico Park. Unlike Ontario, government control in Minnesota, already complicated by three levels of government, is limited by the existence of private land inside the area. Land ownership in the Canoe Area on February 14, 1963, is shown below (from Superior National Forest files).

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FIGURE 4. — This aerial view of Boulder Bay in the southeastern part of Lac La Croix shows the irregular shoreline of the granite regions and an unusual stand of virgin red and white pine. The lighter colored trees in the background are birch and aspen.

Ownership	*Acres*	*Percent*
Federal	736,204	84.4
State	104,111	11.9
County	14,728	1.7
Private[1]	17,197	2.0
Total land (excluding water)	872,240	100.0

[1]Agreements covering Federal purchase of over 4,000 acres of these private lands have been signed and are being processed.

The Quetico-Superior area is managed to maintain a wilderness setting in the ordinary sense of an undeveloped area, without the complete prohibition of timber production. The objective has been to make possible a wilderness-type experience for visitors, rather than to preserve virgin conditions as an end in itself. This is true in Ontario:

> The recreational policy [in Quetico Provincial Park] is to avoid development in the interior and to confine recreational development to the periphery, where campgrounds and picnic grounds will provide facilities and access by water to the interior for wilderness travel.
>
> The policy concerning logging . . . in essence . . . protects the timber within certain limits of shores, canoe routes, and portages. Such timber may be marked for removal only at the discretion of the District Forester.[5]

It is also true in Minnesota:

> . . . the Superior Roadless Areas constitute that portion of the Superior National Forest where, on account of the abundance of lakes and streams and the opportunity for canoe travel and other recreational pursuits under relatively primitive conditions, the policies and forms of management commonly employed on National Forest land call for modification on a scale requiring the approval of the Secretary of Agriculture.
>
> The general purpose of the plan of management is, without unnecessary restrictions on other uses including that of timber, to maintain the primitive character of the areas, particularly in the vicinity of lakes, streams, and portages, and to prevent as far as possible the further intrusion of roads, aircraft, motorboats, and other developments inharmonious with that aim. (Superior National Forest, 1948, p. 1.)

[5] *Wheatley; see footnote 4.*

The policies are designed to restrict the types of changes that have taken place elsewhere in the northern Great Lakes region. Because of the remoteness of the rocky, swampy, ice-scoured terrain and the general lack of high-quality, easily developed resources, much of the border lakes region was late in developing the roads, railroads, logging, struggling cutover farms, resorts, and crossroads hamlets common in other parts of northern Minnesota, Wisconsin, and Michigan. When such changes began to affect the sizable sections passed over in the first sweep of logging, enough people felt that there was something desirable about the now unique roadless, unsettled waterways to object to the changes.

Briefly the regulations for Quetico Park and the Boundary Waters Canoe Area are as follows:

1. All roads are prohibited, except temporary timber access roads closed to public travel.

2. Travel by airplane to or from Quetico Park or the Boundary Waters Canoe Area by the public is prohibited. Air travel to peripheral points of entry to Quetico Park is allowed. Both countries use planes extensively throughout the area for administration, particularly fire patrol.

3. Motorboats are "prohibited except where the employment of such facilities by the public has been well established" in the Boundary Waters Canoe Area; Quetico Park has no motorboating regulation. To date in Minnesota there has been no statement as to where motorboats are excluded, and no enforcement of the ban.

4. No boats or canoes may be stored on public areas (this began in 1961 in Quetico, and was not generally enforced in Minnesota until 1964).

5. No resorts or summer homes are allowed on government land. In Canada this restriction also applies to a one-mile-wide buffer zone around Quetico Park.

6. Logging of shoreline stands is prohibited. In addition, part of the Boundary Waters Canoe Area is closed to all logging (Fig. 5).

7. Mining will be allowed in Quetico Park only if "the resource is absolutely necessary to the national economy," except for rights acquired before 1956, and "only if it is shown conclusively that it is in the long-term public interest to do so" in the Boundary Waters Canoe Area.

8. Water level alterations through building dams are prohibited in most of the Boundary Waters Canoe Area. The Quetico policy is apparently not written, although the International Joint Commission, which

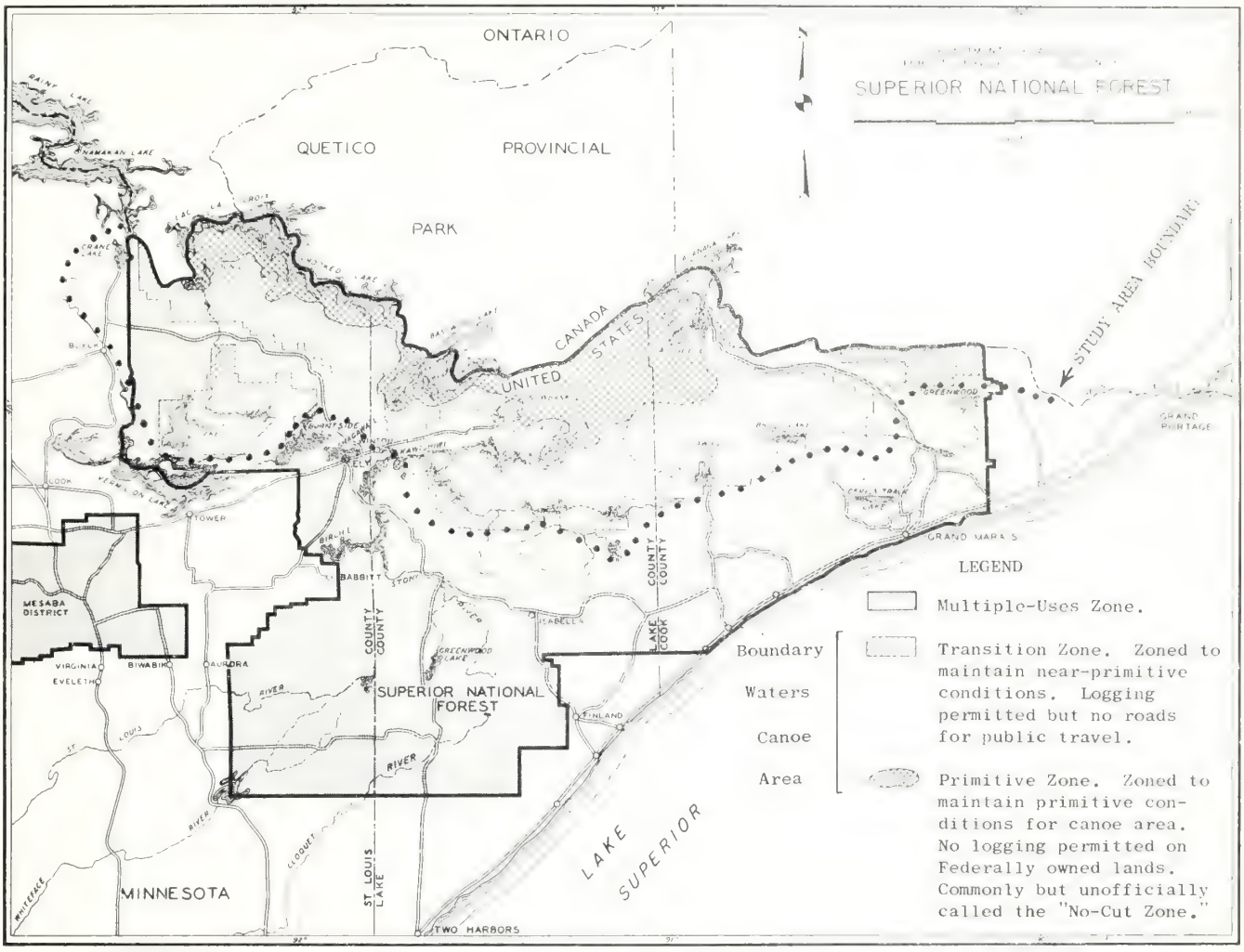

FIGURE 5. — Land use zoning on the Superior National Forest.

is made up of three Canadian and three American citizens ruled unanimously against dams on the Quetico-Superior border waters in 1934.

9. Quetico Park has no legal hunting or trapping (except a few Indian trap lines). Most of the Boundary Waters Canoe Area is now open to hunting and trapping.

10. There are no special regulations on fishing.

11. Developments, such as canoe campsites, portage trails, and docks, are limited and simple. Probably due to heavier use and more motorboat use, the Boundary Waters Canoe Area has more developments and somewhat more elaborate facilities in parts of the area —such as fireplaces, garbage pits, and tables at some campsites.

12. Private land is being purchased or exchanged by the Forest Service to obtain complete public ownership and to eliminate buildings and uses inconsistent with the desired wilderness atmosphere. Land has also been exchanged with other governmental units.

Major Situational Characteristics

Location Relative to Population Centers and Transportation Routes

There is only a small local population near the Boundary Waters Canoe Area, but the population concentrations of the western portions of the American Manufacturing Belt lie no more than 1 to 2 days' drive distant. Chicago is about 580 miles from Ely by road, the Twin Cities about 240 miles.

The Boundary Waters Canoe Area is quite directly linked with the densely populated areas by the highway system, the almost universal means of approach. Since

most visitors come from the south and southeast, the routes focus on the western tip of Lake Superior. The newly opened road around the north side of Lake Superior is longer, and it will probably serve more as an attraction in itself rather than as a route to the Boundary Waters Canoe Area.

Recently highway access to Quetico Park has improved greatly. In 1954, Highway 11 was opened from near Port Arthur to the small mining settlement of Atikokan, on the northern fringe of Quetico Park (Fig. 1). A circuitous route from either eastern or western Canada was still necessary, however. Now Highway 17 along the Lake Superior North Shore brings the Canadian east closer; and an extension of Highway 11 from Atikokan to Fort Frances is being built, which will give the Prairie Provinces direct access. Highway 17 also provides a more direct and shorter route from the central and eastern manufacturing belt of the United States to Quetico's northern entry points. Areas in the United States east of Toledo are now almost as close to Quetico as to the Boundary Waters Canoe Area—only about 100 miles extra driving is required to reach Atikokan instead of Ely.

Location Relative to Other Recreational Areas

Both the Boundary Waters Canoe Area and Quetico Park are surrounded by much recreational land. In Minnesota, however, the surrounding recreational land is more developed. In Ontario large areas of wild land outside Quetico Park are still lightly used. This undoubtedly helps explain why Ontario had few repercussions when private airplane travel was prohibited in Quetico Park, although the same action in Minnesota provoked bitter controversy.

Most officially established Wilderness Areas in the United States are in the Mountain West, remote from the majority of the Nation's population (Fig. 6). These Wilderness Areas are generally even less developed than the Quetico-Superior. Compared to canoe travel, back-packing in the mountains probably is more physically demanding, and using horses more expensive. Most National Parks, which are also usually distant from population concentrations, are much more developed (on a small part of their total area). Thus, the Quetico-Superior is uniquely intermediate to National Parks and National Forest Wilderness Areas in development, easier and cheaper to travel through, and much closer to the users' residences.

For Middle Western people seeking relatively wild conditions, the Quetico-Superior is an intervening opportunity; for those interested in canoeing it has no good substitutes. Land physically similar to the Quetico-Superior is not common in the United States, and much of what is similar has been developed in such a way as to discourage canoe camping. In Canada, on the other hand, alternative areas are more common, more comparable, and closer to populated areas. Algonquin Park, only about 125 miles from Toronto, is also a roadless canoe travel area, although somewhat more developed than is Quetico.

As a result of the distribution of different types of recreational areas, population, and the transport system the Boundary Waters Canoe Area is much more heavily used than the western Wilderness Areas, although less than the National Parks (Fig. 6). Quetico is less used than Algonquin Park, but if only canoeists are compared the difference is small—19,000 in Algonquin and 17,000 in Quetico in 1960 (Quetico Foundation 1960, p. 3).

The relative locational factors lead to predominantly United States use of Quetico Park. In 1960, 89 percent of Quetico visitors were United States citizens compared with only 10 percent at Algonquin (Quetico Foundation 1960, p. 3). Americans were in the majority even at the northern entrance points to Quetico. Canadian use of Quetico Park has increased since auto travel to the Park has become possible, but Americans will probably continue in the majority.

THE STUDY AREA AND PERIOD OF COVERAGE

Data were collected on the use of all of the Boundary Waters Canoe Area and Quetico Park, and also for all of the bodies of water that lay partly inside the two areas. Much of the fringe around the Boundary Waters Canoe Area was also included, so that its three separate parts were joined into a single area (Plate I).

A preliminary field check of use was made from July 1 through Sept. 16, 1960. The main survey was conducted from June 11 through Sept. 9, 1961, and the description of methods refers to 1961. When the records of outfitters, resorts, and youth camps were used, the use figures before and after these dates were kept separate as far as possible.

Although the study period did not cover the full summer season, it did include the period of heaviest use and this was the period of most critical demands upon the resource. The business records of two large canoe outfitters showed that about 90 percent of the canoe trips were taken during the study period.

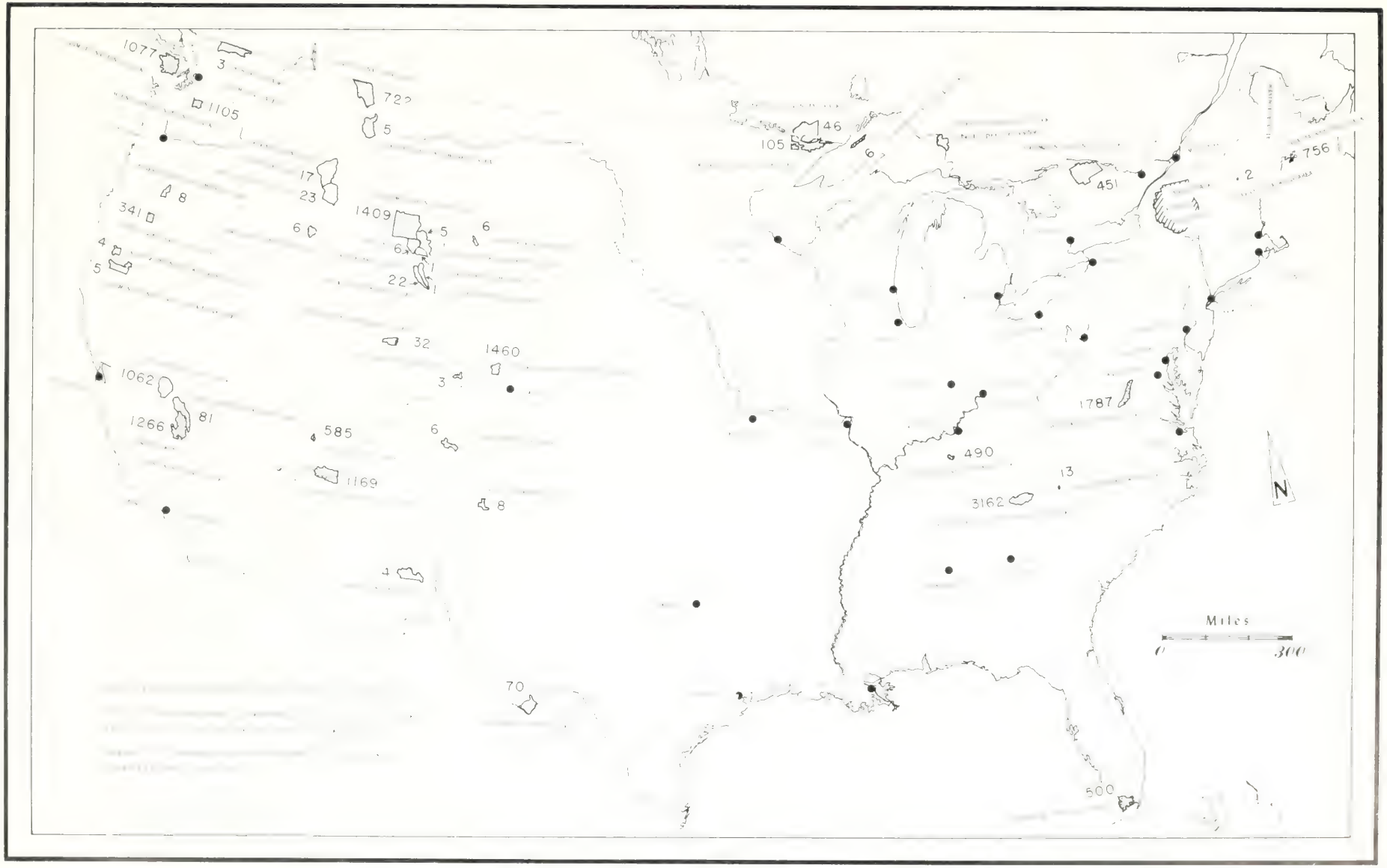

FIGURE 6. - - Visits to selected recreation areas, 1959, in thousands.

The spring fisherman use probably differed in distribution, objectives, attitudes, and requirements for satisfaction, and would present a different range of management problems. After Labor Day some local fishing continued, but most campgrounds and many resorts were nearly empty, all youth camps were closed, and the canoe routes were almost deserted.

Off-season use seems to have increased substantially in the short time since the survey was conducted, perhaps in response to main-season crowding. Judging from observations by Forest Service administrators, visitors are coming in much larger numbers earlier in the spring, later in the fall, and, for a very different sort of recreation, in the winter.

METHODS OF DATA COLLECTION

This is a large area with many and diverse kinds of access used by all sorts of people for many different forms of recreation. Since 1955 the people entering Quetico Park have been recorded by means of travel permits, which include a brief description of the approximate intended route. There was no comparable permit system on the Superior National Forest, but many visitors used the services of outfitters, resorts, or youth camps and they appeared in some form in business records. Usually, however, the records were poorly suited for the collection of the kinds of data needed for this study. Many other people never showed up in any records. Almost all campers had their own equipment, and 33 percent of the canoeists in 1961 did not rent canoes locally. Information on these least known types of users is particularly important for National Forest recreation planning.

For these reasons it was necessary to measure use directly. Since the area is so large and the approach routes relatively few, it seemed most efficient to check the users where they were concentrated on these approaches rather than over the entire area (Plate I). Methods will be briefly described here; details of the sampling design, estimating procedures, and questionnaires are available in mimeographed form upon request to the Station.

The six road-checkpoints chosen covered all but one of the major access points. A simple cumulative pneumatic traffic counter was installed at each location. A 3-foot square sign alerted drivers who were then stopped and interviewed briefly, using a one-page form (Fig. 7). Motorists cooperated very well; only 3 cars out of almost 4,000 refused to stop.

Only outbound daylight (between 8:00 a.m. and 8:00 p.m.) traffic was sampled. This was a minor problem because night traffic was light. However, at night some kinds of recreation probably made up a somewhat smaller proportion of traffic than they did during the day.

Interviews were conducted at the four main checkpoints on 14 randomly selected days, twice on each day of the week. At two minor points, each day of the week was checked only once.

Total traffic for most of the study period was determined directly from the traffic meter readings. The counters were new and quite accurate, and none failed mechanically during 1961. A correction was made for cars pulling trailers and multi-axle trucks, and the corrected total was halved on the assumption that over a 13-week period inbound and outbound traffic were equal. This gave an estimate of over 89,000 outbound vehicles, almost 4,000 of which were checked. Use—amount, type, and location beyond each checkpoint—was estimated by applying the percentages derived from the interviews at that point to the outbound traffic total for that point.

Only one important access point was not covered by the road checkpoints. This was Winton, a town of 200 people on Fall Lake. A road-check was unsuitable because there was no place where recreational vehicles could be checked without also stopping many local drivers. Almost all users appeared on business records, which were checked. One small parking area, not officially a public access, was used by the public. License plates were recorded daily to count groups and measure length of stay, and interviews with a sample of people

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FIGURE 7. — Recreationists leaving the study area were interviewed briefly. Motorists cooperated very well.

returning to their cars gave a basis for estimating types of use.

There were other minor points not covered fully by road checkpoints (Plate I). Business records, all-day checks on portages, and parking lot counts were all used for these lightly visited locations.

The several young people's camps in the study area all used the Canoe Country. Their use was taken directly from their records, and cooperation was complete.

An error term cannot be computed, but a number of cross-checks suggests that it would be small.

Use distribution was estimated from several types of data. Information was collected in the roadside survey on the location of accommodations used and all water areas visited. In addition, 292 long interviews were carried out with a sample from all classes of visitors except auto sightseers. The sample covered the entire study area, except French Lake, Ontario. Detailed information on areas visited was obtained. (This questionnaire also dealt with visitor characteristics and attitudes.) At minor points, where very few groups were contacted, 107 self-addressed forms and maps left on windshields of parked cars supplemented interviews. Almost all of the people filling out these forms were canoeists, and the 79-percent rate of return suggests the depth of their involvement with the area.

The roadside forms were not generally used for mapping canoe routes because canoe routes were often long, complex, and difficult to describe accurately during a necessarily brief interview. For all other types of use, all of the forms were combined to determine the patterns of travel for visitors entering at each access point.

Visitor Totals[6]

An estimated 132,400 people visited the study area from June 11 through Sept. 9, 1961, and all but 3,400 entered the area from the south through Minnesota. Of this total, 51,300 visited only the part of Minnesota outside the Boundary Waters Canoe Area, and did not go to Canada. Another 5,300 visited Minnesota and Canada, but bypassed the Boundary Waters Canoe Area. Those who actually entered the Boundary Waters Canoe Area totaled 72,400, and 25,100 of these crossed the border into Canada, almost all into Quetico Park. The 3,400 who entered from the north came in by way of French Lake, Ontario, and visited only Quetico Park.

Types of Recreation

Visitors were classified on the basis of kind of accommodations used (where they laid their heads at night), and those who camped out on the waterways were further divided into users of boats and canoes

[6] *Visitor here means a person who leaves home to visit the study area. A person is counted as a visitor once, and once only, every time he does this. This differs from the Forest Service statistical unit, the "visit" which involves counting a person each time he enters a reporting unit, such as the Boundary Waters Canoe Area, even from a resort or campground on the same lake outside the unit. The 72,400 visitors made 193,000 visits, so defined, to the Boundary Waters Canoe Area during the 1961 study period. This is almost twice the number of visits estimated by the Superior National Forest for 1960.*

AMOUNTS OF USE

(Table 1). A small number of parties used more than one type of accommodation. For example, a few canoeists camped in an auto campground at the beginning or end of their trip. These groups were classified on the basis of the dominant type of accommodation.

Several points in Table 1 may be emphasized. First, for each part and for the study area as a whole the canoeists (by which is meant people who go on canoe trips, or canoe campers) formed the largest class, and over two thirds of these people paddled. However, if all of the people using motorboats were combined, it would seem that the Canoe Country is really motorboat country (Table 2). The proportions in Table 2 when applied to Table 1 led to the following estimates of visitors by type of back-country travel.

	Boat	*Canoe*	*Neither*
Study Area	61,400	44,600	32,000
Boundary Waters Canoe Area[1]	37,500	38,200	0
Quetico Park	15,700	20,100	0

[1]Several hundred people entered this area by horse, and usually later used boats or canoes. A small number hiked in.

In the study area only about three-fourths as many people canoed as used motorboats, and half as many used neither. Even within the Boundary Waters *Canoe* Area, individuals using motorboats almost equalled those using canoes. Quetico Park had somewhat less boat use, proportionately. The figures all add up to slightly more than total visitors because some people used both boats and canoes. However, most *visits* to

TABLE 1. — *Estimated number of visitors, June 11 through Sept. 9, 1961*

Type of visitor [1/]	Total study area	Total Minnesota study area	Boundary Waters Canoe Area	Quetico and fringe
Canoeists:	32,100	31,700	30,700	15,000
Paddling	22,900	22,600	22,300	10,500
Motorized	9,200	9,100	8,400	[2/] 4,500
Campground campers	14,400	13,400	7,700	[2/] 2,600
Boat campers	13,500	12,500	7,800	4,400
Resort guests	25,900	25,900	16,000	8,400
Private cabin users	7,700	7,700	3,000	2,000
Other overnight users	500	500	500	100
Day users	11,100	10,100	6,700	1,300
Auto sightseers	27,200	27,200	0	0
Total	132,400	129,000	72,400	33,800

1/ The boat-camper category includes about 350 people who camped at undeveloped sites at the ends of minor roads, rather than out on the lakes. Houseboats are classed with resorts here and in subsequent tables. Day users include all 1-day use by people staying at their homes or driving in from resorts and so on outside the area, except auto sightseers. The columns are not mutually exclusive: for example, everybody counted in the B.W.C.A. is also counted in the Minnesota study area. Quetico Park statistics are based on this survey except for French Lake, for which travel permits supplied by the Ontario Department of Lands and Forests were checked.

2/ Does not include a large, but unknown, number of people who did not travel beyond French Lake.

TABLE 2. — *Percentage of groups in selected recreation classes using boats and canoes*[1]

Type of visitor	Groups in sample	Boat only	Canoe only	Both	Neither
	Number	Percent	Percent	Percent	Percent
Study area:					
Campground campers	96	46	28	4	22
Boat campers	24	92	0	8	0
Resort guests	53	85	6	9	0
Private cabin users	21	71	0	29	0
Day users	9	56	0	0	44
Boundary Waters Canoe Area:					
Campground campers	53	56	38	6	0
Boat campers	24	92	0	8	0
Resort guests	49	84	4	12	0
Private cabin users	14	79	0	21	0
Day users	3	100	0	0	0
Quetico Park: [2/]					
Campground campers	4	25	50	25	0
Boat campers	6	83	0	17	0
Resort guests	14	79	14	7	0
Private cabin users	3	67	33	0	0
Day users	2	100	0	0	0

1/ Data are taken from long-interview forms.

2/ Also includes a small number of users of Canada immediately east or west of the Park but within the study area.

the Boundary Waters Canoe Area were by boat (117,000 compared to 76,000 that used canoes).

Except for the canoeists, boat campers, and the few visitors to resorts or cabins inside the Boundary Waters Canoe Area, all visits were quick forays from the fringe, in and out again the same day. About 41 percent of the visitors to the Boundary Waters never stayed overnight in the interior; this group made some 118,000 of the 193,000 visits. This was unexpected. Official estimates of average length of stay per visit (Forest Service definition) to the Canoe Area has been as high as 5 days, but the true value appears to be only about 1.75 days. A large area has been set aside for people to drink deeply of the wild landscape, but many only sip. The same predominance of brief, marginal visits is quite possibly characteristic generally of Wilderness Areas, National Parks, and other undeveloped recreation areas.[7]

[7] *Research by the Pacific Northwest Forest and Range Experiment Station had indicated a somewhat similar situation in Oregon Wilderness Areas. In the Three Sisters Wilderness Area, 80 percent of all visits were day-visits, but because the Three Sisters is much smaller than the Boundary Waters Canoe Area, a larger proportion of these people reached the central parts. (From unpublished findings.)*

Auto sightseers are almost as numerous as canoeists. The most common form of outdoor recreation in the United States (and probably in Canada) is viewing the outdoors through a car's windshield (Outdoor Recreation Resources Review Commission, 1962a, Table 1), but it is somewhat surprising to find so much of it here, in an area which is famous for very active recreation and where nothing has been done to provide for auto touring. Perhaps the wilderness lures these drivers on, even though they do not enter the established area.

Almost as many campers camped away from the auto campgrounds as in them (not counting canoeists as campers). Within the Boundary Waters Canoe Area the boat campers outnumbered the people visiting the Canoe Area from the fringe auto campgrounds.

The use of the Quetico-Superior by resort guests was heavy. People entering the Canoe Country from the fringe resorts outnumbered those from the resorts located inside the Boundary Waters Canoe Area 3 to 1. These resorts on the edge of the wilderness have an advantageous situation unique in the Lake States.

DISTRIBUTION OF USE

The distribution of use is described here primarily by means of maps. First, use is classified as before by type of accommodations used, with a further subdivision of visitors who camped within the Canoe Country into paddling and motor canoeists, and boat campers. Next, use is classified by type of water travel (boats or canoes). Looking at use in these two different ways provides a better understanding of factors that seem to influence the patterns and also shows some important relations to the capacity problem. A map of the dominant type of use (motorboating or canoeing) and a map of total use are also included. The patterns are analyzed in the section following the descriptions.

All of the discussion of use distribution is in terms of groups. Groups can be converted to number of individuals or man-days by using the average group sizes and stays given in Table 3. A *group* refers to people staying in or traveling through the study area together—a family, several friends, a Boy Scout troop, or even a lone person.

Use by Type of Accommodations

The distribution of each type of use (except auto sightseers) is mapped, and the major features of each map are pointed out below. The two types of canoeists (paddlers and motorized) show similar patterns. Auto campers are distinct, but boat campers, resort guests, and visitors to private cabins all were distributed in much the same way. The day users were distributed differently than the other types, and so were auto sightseers.

Paddling Canoeist Use

Paddling canoeists were concentrated in the central area, and access points varied more in amount of use than was true for any of the other types of visitors (Plate II). Over 2,600 groups paddled Moose Lake, the most heavily used area. No other type of use reached such a high level on any lake.

Use gradients were gradual, and virtually all of the area was used. Three axes from Moose Lake—east, north, and west—were followed by moderately large numbers of paddlers much farther than by any other visitor types. Even as deep as Kawnipi Lake, 25 miles to the north, canoeist use was heavier than on any access lake except Moose. All of the southern study-area fringe, however, was very lightly used. Unused areas were generally not the most remote, but rather smaller, cul-de-sac lakes scattered widely. Use

TABLE 3. — *Average group size and length of stay for major visitor classes, June 11 through Sept. 9, 1961*[1]

Visitor class	Average group size (individuals)		Average length of stay[2] (days)	
	Study area	B.W.C.A.	Study area	B.W.C.A.
Canoeists:	4.7	4.7	6.8	4.8
Paddling, no youth groups	4.3	4.3	7.1	5.1
Paddling, youth groups	10.0	10.0	8.6	5.0
All paddling canoeists	5.0	5.0	7.2	5.1
Motorized	4.0	4.0	5.7	4.2
Campground campers	3.7	3.7	4.0	4.3
Boat campers	3.6	3.6	4.2	3.9
Resort guests	3.5	3.3	5.8	5.1
Private cabin users	3.4	3.3	6.2	5.7
Day users	3.0	2.7	1.0	1.0
Auto sightseers	3.3	0	1.0	0
Total	3.7	3.9	4.1	4.4

1/ Data on Quetico Park were not separated.

2/ This refers to the total stay in the area, not the Forest Service "visit." Any part of a day was counted as a whole day for sample groups. For example, a group that entered the study area at 10:00 p.m., camped, and left at 8:00 a.m. the next morning, was credited with a 2-day stay. From roadside survey and business records.

from French Lake in Quetico Park overlapped use from the south only slightly.

Motor Canoeist Use

The distribution of motor canoeist use (Plate III) was similar to that of paddling canoeists, but use was at a lower level—only about 40 percent as great. The percentage using Moose Lake was almost as high.

The use gradients, however, were steeper than for paddlers, and a large area, particularly in Quetico Park, and some sections of the Boundary Waters Canoe Area were unused. Like the paddlers, motor canoeists made only light use of the southern area. Use from French Lake did not overlap use from Minnesota.

Auto Campground Use

Plate IV shows the use of the lakes and rivers of the study area by people who used the auto campgrounds. Because only 85 percent of these groups used the lakes, the map does not show the use of the campgrounds themselves; this information is included in Table 4.

The distribution of camper use was extremely uneven, ranging from an estimated 20 to 790 groups per campground. For some places it was very heavy relative to the number of family camp units. Use of the lakes also tended to be very uneven (Plate IV). A very large part of the study area was not used by auto campers at all. Few portaged from the lakes or rivers on which the campgrounds were located; total groups over the first portage were only 18 percent of those who used the fringe waters.

Boat Camper Use

Boat camper use reached moderately heavy levels (Plate V), especially at Crane and Sandpoint Lakes in the west. All of the road-end lakes, including French and Pickerel Lakes in Quetico Park, had moderate use, and so did most of the border lakes. Boat campers did not use most of Quetico Park, the Fernberg to Gunflint area, and smaller areas along the Echo Trail. The southern edge of the study area, especially the central area, was very lightly used. Use gradients were steep.

Resort Use

Use by resort guests was heavier at the most popular locations than was auto or boat camper use, but again the distribution ran to extremes (Plate VI). There was a steep gradient from heavy use on the lakes where resorts were located to light use or no use

over the portages, although the decline was not as steep as for campground users. The only exceptions were the several mechanized portages, most of which were heavily used by boaters. Rail or truck portages were particularly important at Trout Lake, Lac La Croix, and Basswood Lake. An almost continuous band of resort use on the border lakes tied together the three lobes of a distribution which was otherwise mainly close to the roads. Crooked Lake and Knife Lake were lightly used links in this border chain.

The northwest portion of Quetico Park had some resort use based on seaplane service to the Beaverhouse Lake Park entry point, mainly from the Crane Lake resorts.

Resort guests did not use most of the study area. The sample did not show any resort use in a large block of Quetico Park, a fairly large portion of the Boundary Waters Canoe Area between the Fernberg Road and the Gunflint Trail, and a narrow band between the Echo Trail and the border lakes. About 38 percent as many groups used lakes beyond one unmechanized portage as used the fringe lakes.

Private Cabin Use

Private cabin use (Plate VII) was similar to that of boat campers and resort guests. It was spotty and generally light (except in the west at Crane and Sandpoint Lakes), and covered only a small part of the Boundary Waters Canoe Area and almost none of Quetico Park. The large south-central part of the Boundary Waters Area was unused. There was little use of the lakes beyond the road-accessible fringe and the lakes reached by mechanized routes, so that the use gradient was abrupt.

TABLE 4. — *Number and use of developed family camp units; percent using the lake or river on which the campground is located; June 11 through Sept. 9, 1961*

Campgrounds 1/	Developed units	Total groups	Groups per unit 2/	Percent using the lake or river
Lake Jeanette	8	360	45	86
Meander Lake	3	20	7	100
Portage River	3	40	13	0
Nels Lake	0	90	-	100
Fenske Lake	14	110	8	67
Fall Lake	0	100	-	100
Moose Lake	6	270	45	89
Lake One	5	100	20	100
Kawishiwi Lake	5	50	10	100
Sawbill Lake	30	540	18	100
Brule Lake	2	70	35	100
East Bearskin Lake	9	200	22	90
Flour Lake	9	150	17	77
Iron Lake	6	170	28	27
Trail's End	39	790	20	81
McFarland Lake	3	110	37	100
Total	142	3,170	21	3/ 85

1/ All of the Minnesota campgrounds are the responsibility of the Superior National Forest except the last, McFarland Lake, which was built by Cook County. There was only one campground adjacent to Quetico Park, at French Lake. It had 110 family units, and an estimated 245 groups camping there visited Quetico Park.

2/ Data for Nels and Fall Lakes were omitted because neither had developed camping units (fireplace, table, tent space).

3/ The 85-percent figure, as well as all of the other data in this table, comes from the roadside sample. The smaller campground sample used for table 2 indicated 78 percent used the lakes.

One-Day Use

Use by people who did not stay overnight in the study area was limited to the outer margins of the Canoe Country and was nowhere heavy (Plate VIII). It was not, however, as marginal as auto campground use; Basswood Lake and Lac La Croix were reached by day visitors but not by sample campground users. Fall Lake, rather than Moose or Crane Lake, had the heaviest use. (Use for swimming or fishing from the shore was not mapped as use of the lakes.) Pickerel Lake in Quetico also had considerable day use.

Auto Sightseeing

Auto sightseers, by definition, did not stay overnight in the study area nor use the lakes. The number of groups sightseeing on each of the six roads at the checkpoint locations is given below (estimated from the roadside survey):

Road	*Total Groups*
Crane Lake Road	780
Echo Trail	1,080
Fernberg Road	1,880
Sawbill Trail	750
Gunflint Trail	3,110
McFarland Road (Arrowhead Trail)	650
TOTAL	8,250

The variation appears substantial, but in fact this was the most evenly distributed of all the uses. The three most used locations were all on blacktop.

Use by Type of Water Travel

Use of boats and canoes cuts across the accommodation classification to some extent. Canoeists, of course, used canoes, but auto campers used both boats and canoes substantially (Table 2). The other accommodation types were mainly boat users, but not exclusively so. The type of craft used strongly affected the circulation patterns beyond the access points, regardless of the type of accommodations.

Canoe Use

Total canoeing (Plate IX) differs only in detail from the maps of paddling canoeists (Plate II) and motor canoeists (Plate III). The largest increase is near the two largest campgrounds: Trail's End between Saganaga and Seagull Lakes, and Sawbill Lake. Canoe outfitters adjoined both of these large campgrounds. Axes of very heavy canoe use led from Moose Lake northeast to Saganaga, and Moose Lake north to Agnes. Heavy use was also made of the waterways from Fall Lake north to Basswood and west along the International Border, and in a circle east from Moose through Insula and back west to Lake One. Almost all of the study area was visited, but the southern margin was lightly used everywhere except Sawbill Lake.

Motorboat Use

The distribution of all motorboat use (Plate X) is a map of extremes. Some sections were heavily used, especially along the western International Border, but most of the area was not visited. Levels of intermediate use were rare: unused lakes lay next to very heavily used waters. A large area in Quetico Park had no boats, but the only sizable boatless section in Minnesota was between the Fernberg Road and the Gunflint Trail.

Dominant Use

The maps of canoeing and motorboating are the bases for the map of dominant use (Plate XI). Canoeing dominated most of the area; but in general wherever motorboats were used at all, boating dominated. There were some exceptions, particularly Moose Lake and Lake One, but these were the only lakes directly accessible to boats where canoeing groups outnumbered boaters. The large border lakes with mechanized portages were boat-dominated except for Crooked Lake. In Quetico Park, away from the International Border, only Pickerel Lake had more boats than canoes. The proportion of the Boundary Waters Canoe Area used mainly by boating groups was higher than for Quetico Park.

Total Use

Total use by all types of visitors (Plate XII) was heavy on the border lakes from Crane Lake east to Saganaga (with lighter use on Crooked Lake); from Moose Lake and Fall Lake north to Agnes and Kawnipi; from Moose and Lake One east halfway to the Gunflint Trail; on and near Sawbill, Seagull, and McFarland Lakes; on Trout Lake; and on Pickerel Lake. The map could be generalized as showing particularly heavy use where roads or mechanized portages reached large lakes and on the two heavy axes from Moose Lake to Knife Lake and from Moose Lake to Kawnipi Lake.

FACTORS RELATED TO USE DISTRIBUTION

Explaining the distributions that have been described involves two aspects: visitors' choices of starting points or bases of operation, and how far and which way they go from home base. Different factors seem related to each of these aspects. Choice of starting point differs primarily with the type of accommodation used, and each type is discussed here. The next section considers movement out from starting points, which differs with the type of water travel—boat or canoe.

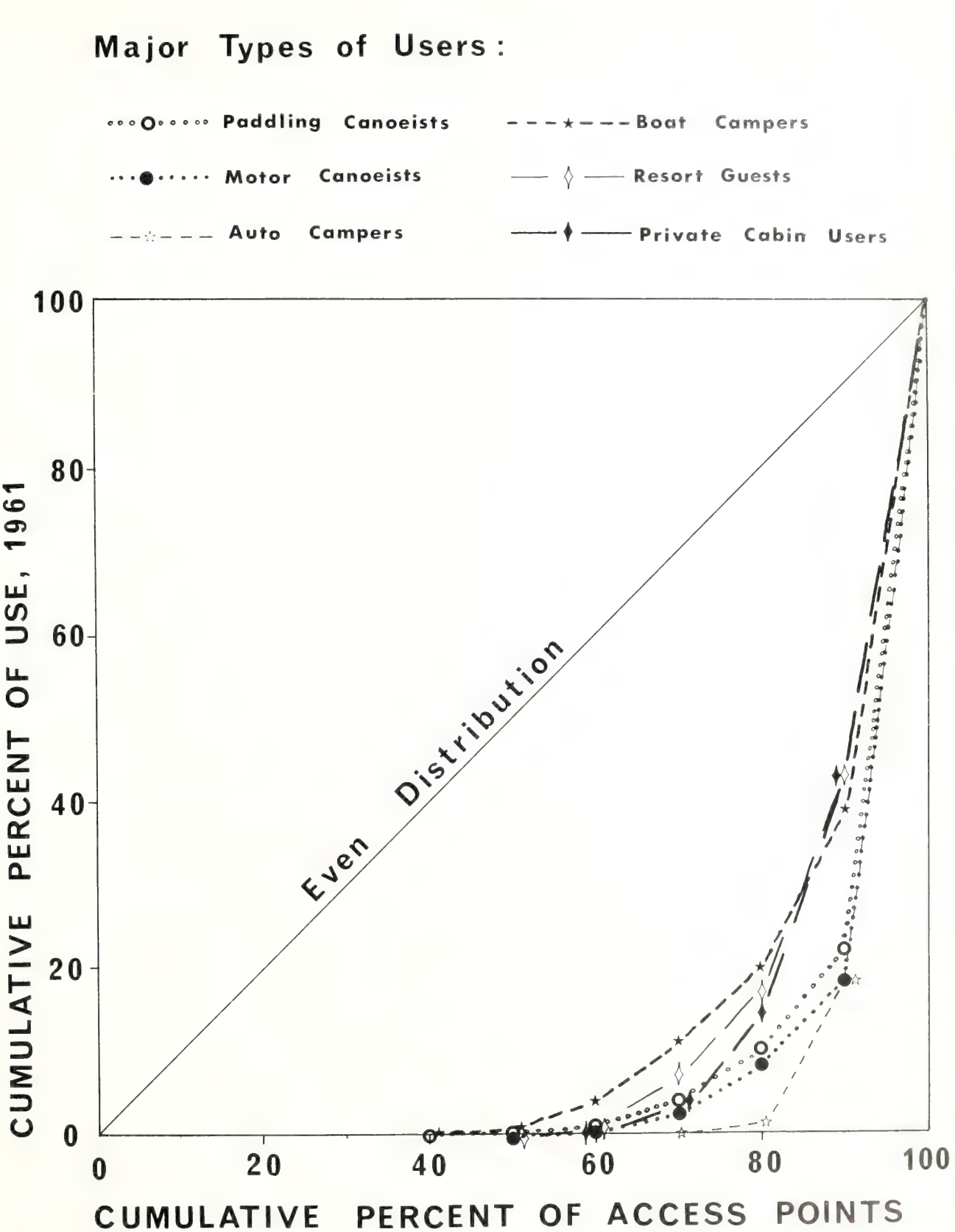


FIGURE 8. — The concentration of access point use in 1961 is shown on this Lorenz diagram. If every access point were used equally, that use would be represented by a line at 45 degrees through the origin. The more a line deviates from the 45-degree line, the more uneven (concentrated) that use is.

TABLE 5. — *Characteristics of access points in relation to number of paddling canoeist groups using the points, June 11 through Sept. 9, 1961 (data for Moose Lake omitted)*

Characteristics of access points	Number of access points		Number of groups using the access points		
	Used	Unused	Average[1]	Minimum	Maximum
INDIVIDUAL CHARACTERISTICS					
1. Portage from car to water:					
None required	28	17	78	0	426
One required	5	11	47	0	110
2. Type of waterbody:					
Large lake[2]	16	3	121	0	426
Small lake	12	19	22	0	83
River	5	6	47	0	110
3. Relation to major route: [3]					
On a major route	23	7	99	0	426
Not on a major route	10	21	16	0	45
4. Portage to Canada: [4]					
One or less	6	0	191	17	426
Two or more	27	28	47	0	211
5. Portage to Quetico: [4]					
One or less	3	0	314	247	426
Two or more	30	25	50	0	211
6. Canoe outfitter[5] at access point:					
Yes	15	2	135	0	426
No	18	26	23	0	110
COMBINED CHARACTERISTICS					
A. Direct access, large lake on route, Quetico close, outfitter[4]	3	0	314	247	426
(With Moose Lake)	4	0	897	247	2,644
B. Direct access, large lake, on route, outfitter	7	1	120	0	211
C. Direct access, large lake, on route	3	0	21	8	38
D. Direct access, large lake, outfitter	1	0	10	-	-
E. Direct access, large lake	1	1	5	0	5
F. Direct access, small lake, on route, outfitter	2	1	56	0	83
G. Direct access, small lake, on route	3	2	13	0	20
H. Direct access, small lake, outfitter	1	0	45	-	-
I. Direct access, small lake	3	6	7	0	10
J. Direct access, river, on route	1	2	15	0	15
K. Direct access, river	1	2	33	0	33
L. Portage access, large lake, on route	0	1	0	-	-
M. Portage access, small lake	3	10	16	0	22
N. Portage access, river, on route	3	0	62	16	110
O. Portage access, river	0	2	0	-	-

1/ Average computed only for locations that were used.

2/ Large lakes were over 3 miles long.

3/ Major routes were those shown on the 1958 Boundary Waters Canoe Area recreation map issued by the Forest Service.

4/ Pickerel Lake, Ontario, was omitted; 71 groups were estimated there.

5/ Young people's camps were considered as "outfitters."

6/ "Direct access" as used here means "no portage from car to water." Characteristic No. 4 (one portage from Canada) was not considered.

Factors Related to Use of Starting Points

Starting points were used very unevenly by all visitor types. Ten percent of the access points accounted for over half of every major type of use (Fig. 8). Auto camping was the most concentrated type. Auto camping, resort use, and private cabin use all depend upon fixed improvements. Therefore, the number of lakes with campgrounds, resorts, or cabins largely explains the shape of the three curves in Figure 8. Nevertheless, resort and private cabin use of marginal lakes was *more* dispersed than use by canoeists, especially motor canoeists. Boat camper use and resort guest use of access points were the most evenly distributed.

Paddling Canoeist Use

Within the study area, 62 places provided possible starting points for canoe trips, but only 34 of these had measured use. Use pressure varied in the extreme. Of the estimated 5,100 groups of paddling canoeists, 52 percent started from Moose Lake. Although Fall Lake was second highest, it had only 8 percent of the total. Saganaga Lake was the only other point where as many as 5 percent began their trips.

Explaining this distribution becomes mainly a problem of explaining Moose Lake's heavy use.

The Boy Scouts maintained the largest young people's camp in the study area on Moose Lake, but this accounted for only 230 of the estimated 2,650 groups using Moose Lake as a gateway. Moose Lake has everything: two canoe outfitters located directly on the lake, several resorts that rented a few canoes, a campground and public access point, the Scout canoe base, a direct water route to Canada and a Quetico Park entry point, and three important canoe routes fanning out in Minnesota (or along the border) plus three or four more routes into Canada. It is deep in the Canoe Country and, unlike many of the unused access lakes, it is at the end of the line and cannot be bypassed on the road to start at some deeper spot.

The attraction of Quetico Park was extremely strong. Almost three fourths (73 percent) of the canoe parties that paddled out from Moose Lake went through Prairie Portage and into Quetico Park. By way of comparison, only about 30 percent of all paddling canoeists starting in Minnesota at all other access points went to Canada. Prairie Portage was the most used of the four Ontario Lands and Forest Ranger Stations on the border.

Table 5 shows the relation of use of starting points to six locational characteristics, first taken singly and then grouped. The consideration of each factor in isolation is not completely satisfactory because of unstudied interactions between factors. Because Moose Lake is unique, it is omitted.

Access points within one portage of Quetico Park (item number 5 in the table) seemed most heavily used. Location relative to Canada in general seemed less related, although still strong, as was the presence of an outfitter, location on a large lake, and location on a major route. Direct access (no portage from parking lot to water) was associated with only slightly higher than average use.

The combination of the six characteristics would produce a cumbersome classification, and to reduce the number, access to Canada was omitted in the lower part of Table 5 because it was less related than Quetico Park access. The distinction between the lakes with all five qualities and all other locations seemed large, even without Moose Lake. As the number of portages to Quetico Park increased, use dropped, even though all other qualities were still present (B, Table 5). Where outfitting was absent use dropped sharply again, even where there was direct access. Only Moose River and the Little Indian Sioux River (N, Table 5) had much use where direct access and outfitting were both lacking. The one large lake without direct access (L, Table 5) was Trout Lake, reached across big, heavily used Lake Vermilion; this atypical location was unused.

Inspection of Plate II also indicates a tendency to neglect starting points not leading to routes to the north. The entire area south of the Echo Trail was almost unused. Travel was possible upstream on both the Little Indian Sioux River and the Moose River, but only one sample party used the upper Moose River and none used the upper Indian Sioux. Other starting points on routes not heading northward, such as the North and South Kawishiwi Rivers and Isabella River, had relatively little use. Access points in the eastern slate area, with its east-west grain, were not heavily used. Of the starting points without a strong northward orientation, only Lake One and Sawbill Lake, both of which have resorts, outfitters, and campgrounds, had much use.

Distance from place of residence was not associated with declining use. Nearly half of the paddlers resided in Minnesota, but few local people paddled canoes. (Figure 9 and Table 6 together show distribution of visitors by place of residence.) Since about 90 percent of the paddlers lived south of Duluth, road mileage from Duluth to the access points was taken as a measure of relative remoteness. No relationship was apparent (Fig. 10). This is an exception to the location theories describing consumer behavior. It suggests that recreation, or at least wilderness recreation, is quite different from other services. Gravel road mileage also seemed unassociated with use.

The bulk of the paddling canoeists seemed to have rather strong and similar preferences for access points:

TABLE 6. — *Place of residence of individual visitors, by types*[1]
(Percent)

Place of residence of individuals	Canoeists		Campers		Others		
	Motor	Paddle	Auto	Boat	Resort guests	Private cabin	Day use
Minnesota:[2]							
Local	6	*	2	6	*	6	43
Other NE Minn.	13	11	26	28	10	26	30
Mpls.-St. Paul S.M.A.	28	24	49	32	33	23	10
Other Minnesota	9	11	8	17	6	13	3
Total	56	46	85	83	49	68	86
Dakotas	5	1	*	0	*	0	0
Iowa	5	4	*	5	7	2	1
Chicago S.M.A.	13	9	3	1	16	7	3
Other Illinois	6	4	1	1	6	0	3
Superior, Wis.	1	0	1	2	1	0	0
Other Wisconsin	7	12	3	2	5	2	3
Mich., Ohio, Ind.	3	9	3	4	9	15	0
Mo., Kans., Neb.	2	11	1	2	3	2	0
Northeast[3]	0	0	1	*	1	2	0
South[4]	2	4	*	0	3	1	4
West[5]	0	*	1	*	0	0	0
Canada	0	0	0	0	0	1	0
Total outside Minnesota	44	54	15	17	51	32	14

* Less than half of one percent

1/ Based upon roadside sample data, and excluding visitors to young people's camps.

2/ See figure 21 for definitions of areal categories in Minnesota.

3/ Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, and Pennsylvania.

4/ Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, and Texas.

5/ Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, California, Oregon, Washington, Hawaii, and Alaska.

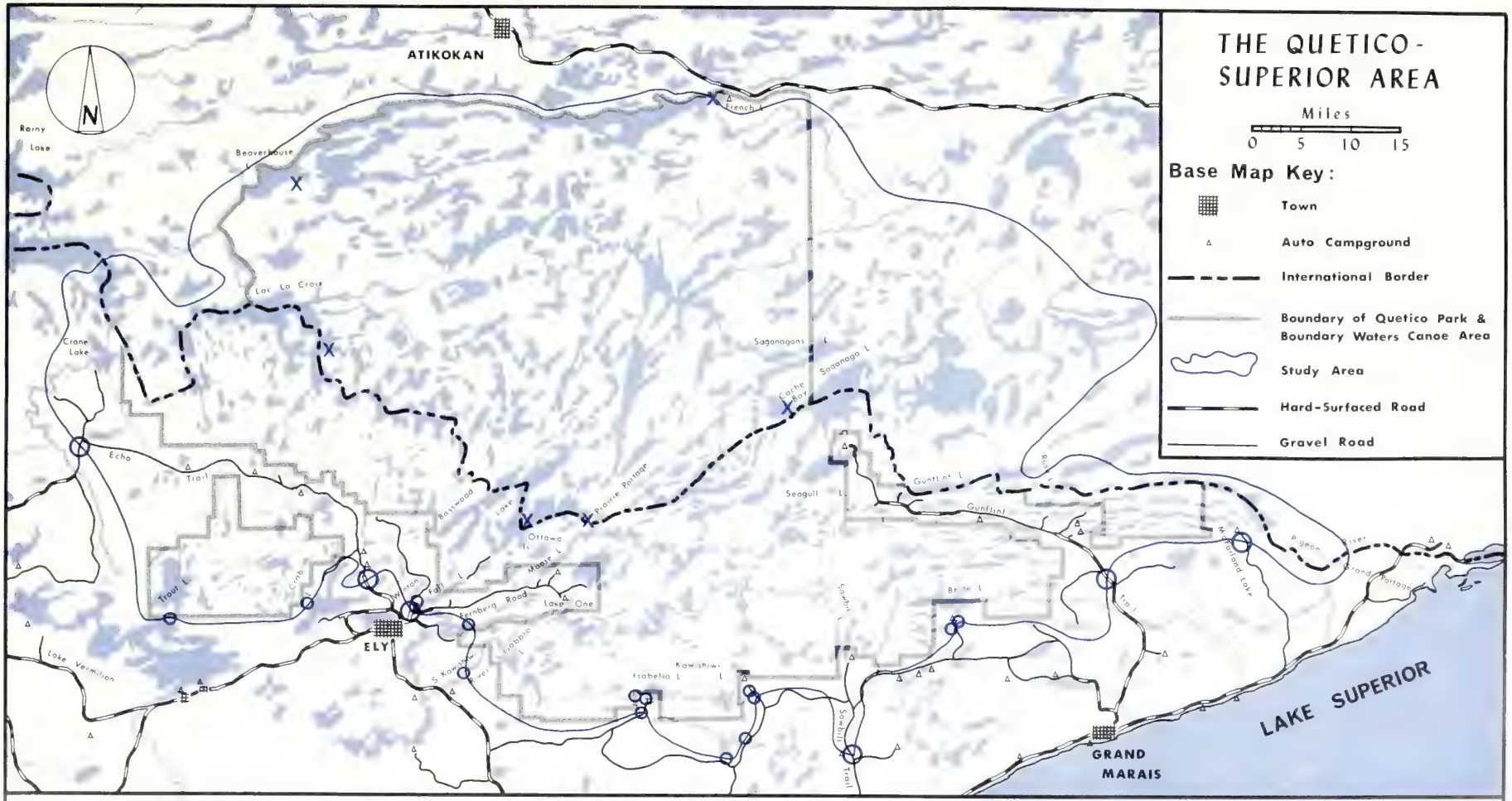
routes leading north to Quetico Park from a location with an outfitter, usually on a large lake and a major route.

Motor Canoeist Use

Of the 62 access points, motor canoeists used only 29 compared to the 34 used by paddling canoeists.

Use by motor canoeists was not quite as concentrated at Moose Lake, but 6 or 7 points accounted for almost all use. Moose Lake still led, but with 44 percent of the total instead of 52. Fall Lake was still second, but with 13 percent of all use instead of 8. Crane Lake, Lake One, and Saganaga Lake each were used by about 7 percent of the motor canoeist groups. No other point had more than 100 groups.

Moose Lake's attractions have been discussed. Again, Quetico Park was a major explanation of Moose Lake's popularity. Half of the 50 sample motor canoeists starting there went to Quetico. About 36 percent of the motor canoeists starting at all other Minnesota points went to Canada. Fall Lake, the second most used location, was also a large lake and directly accessible, had outfitters and a campground of sorts, and was on a major route which reached Canada and Quetico by two short foot portages or one 4-mile truck portage. Crane Lake was the only location used by more motor canoeists than paddlers. The lower popularity of Crane Lake with paddlers may have been due to the heavy motorboat use which would have been encountered for the first two days.



Use Checkpoint Key:

- O Location of traffic counters and roadside interviews
- o Location of portages and access points checked
- X Quetico Park entry points

PLATE I. — The study area and use check points.

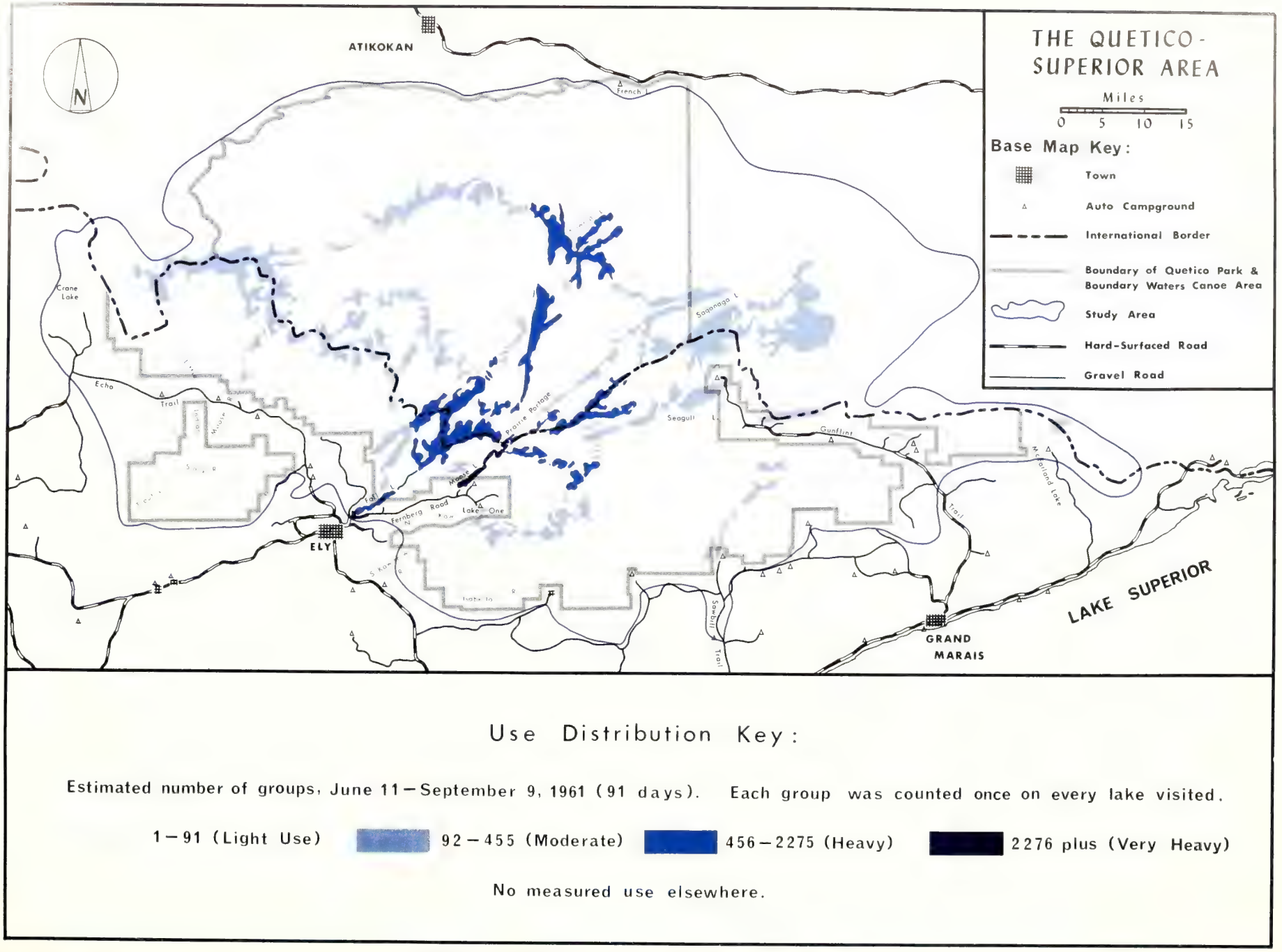


PLATE II. — The distribution of paddling canoeist use.

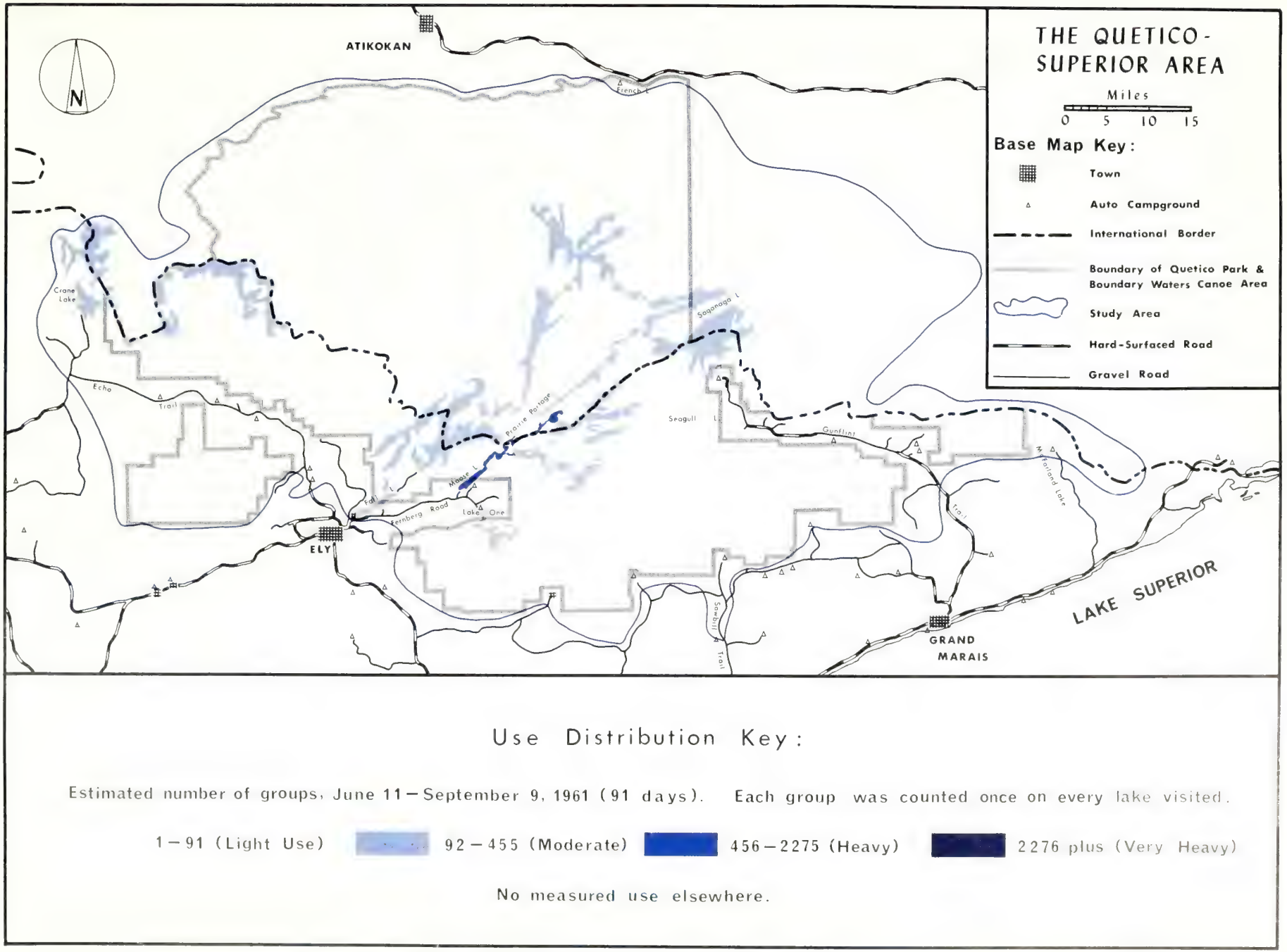


PLATE III. — The distribution of motor canoeist use.

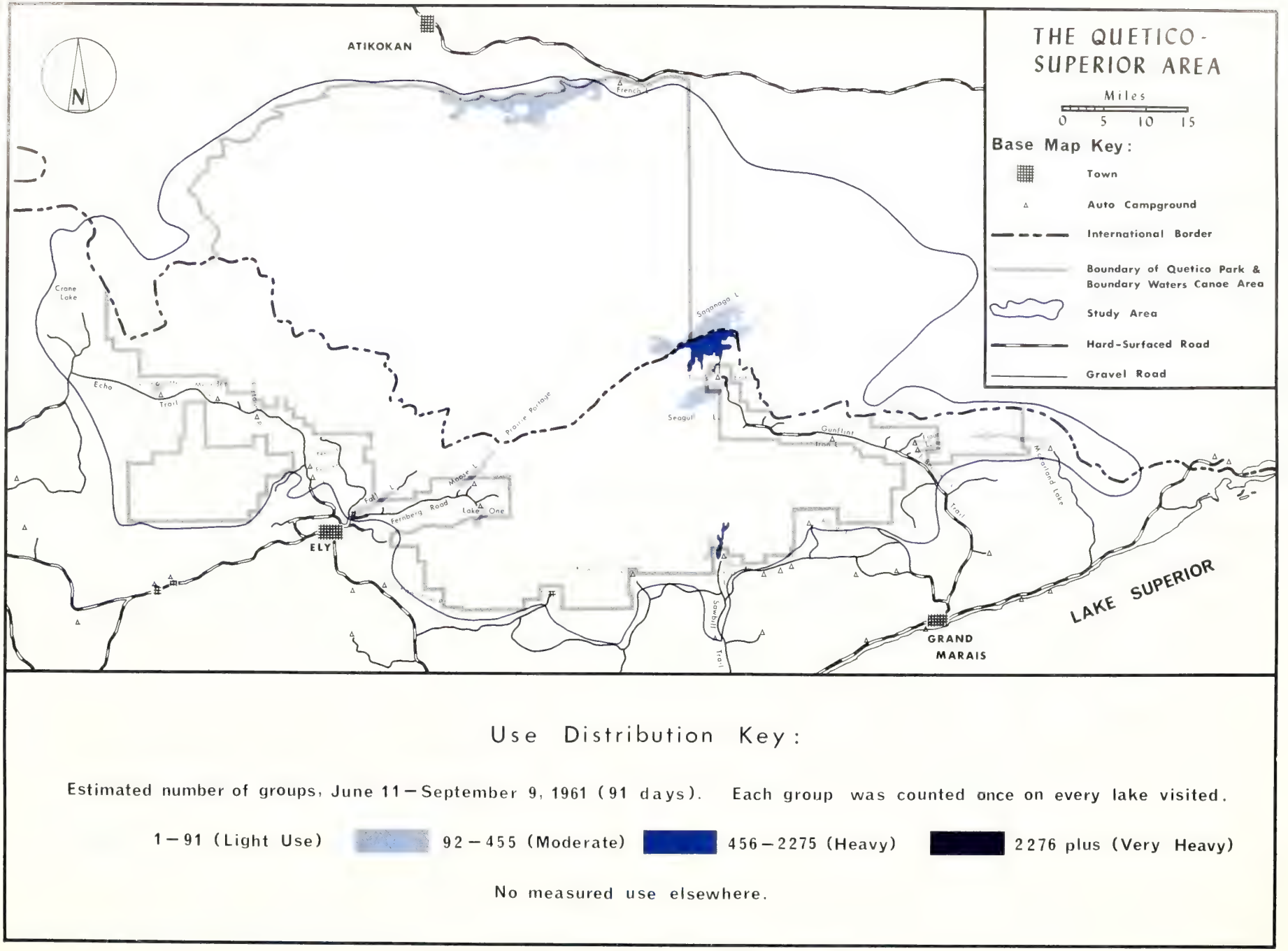


PLATE IV. — The distribution of auto camper use.

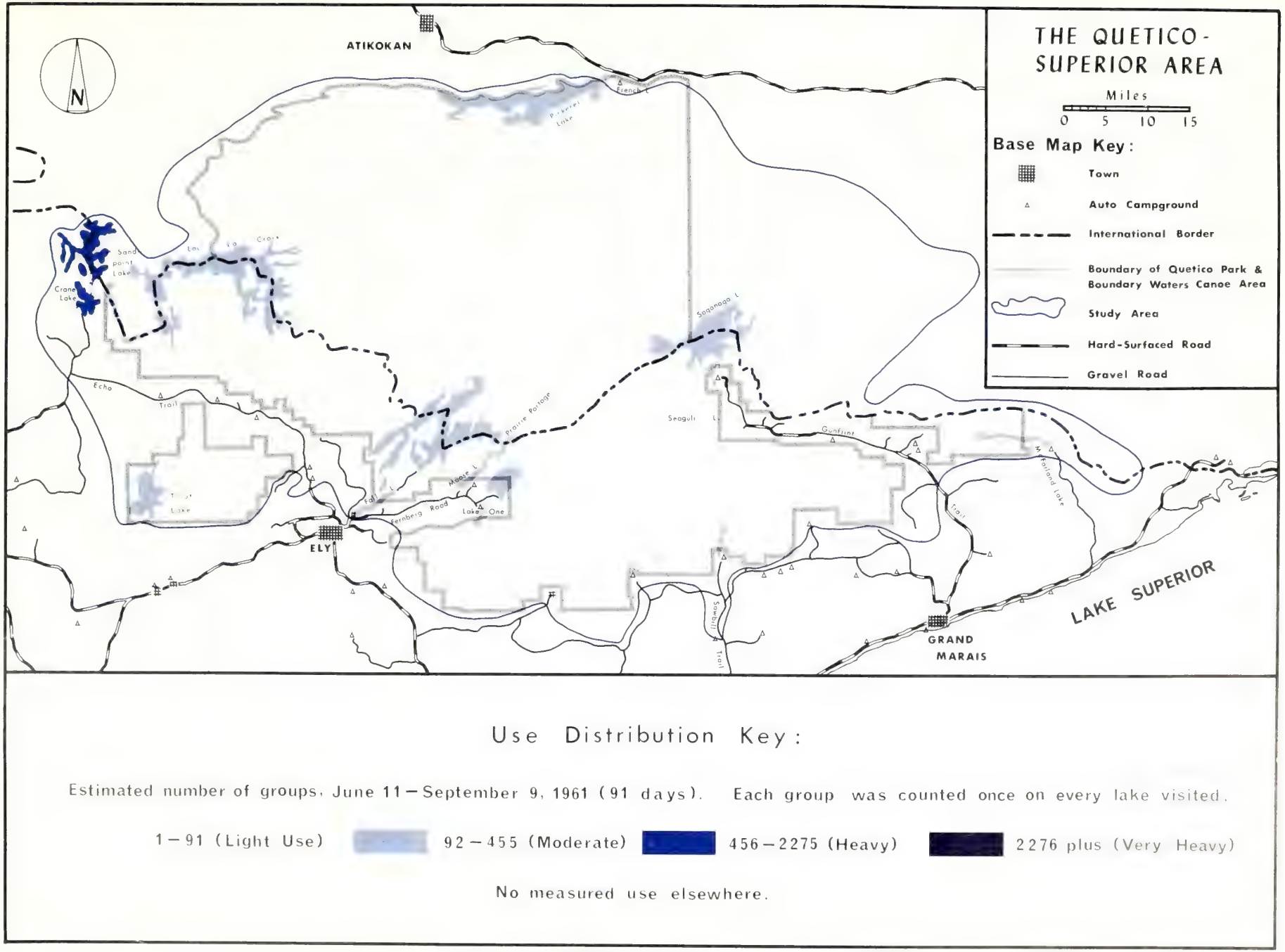


PLATE V. — The distribution of boat camper use.

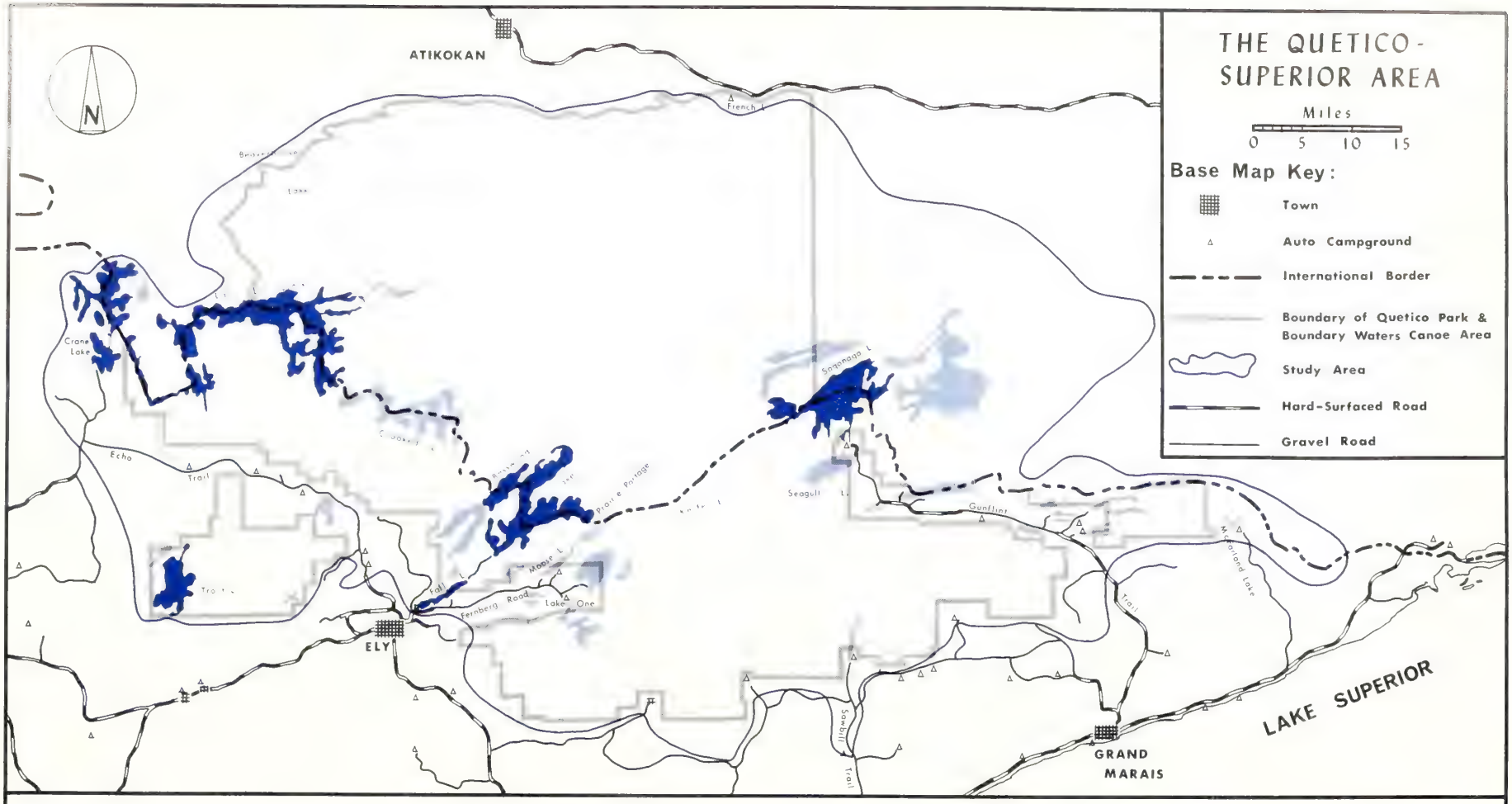


PLATE VI. — The distribution of resort use.

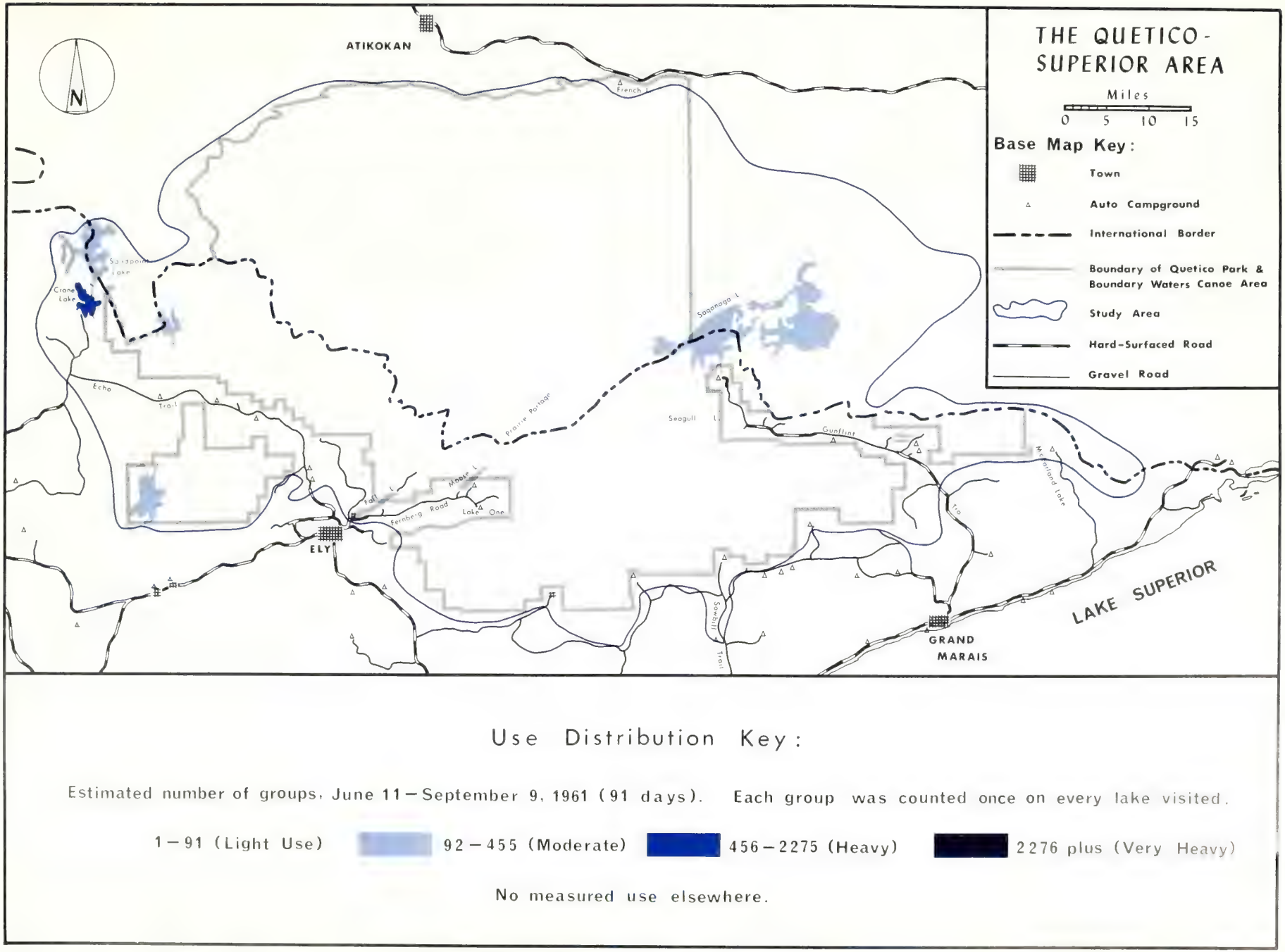


PLATE VII. The distribution of private cabin use.

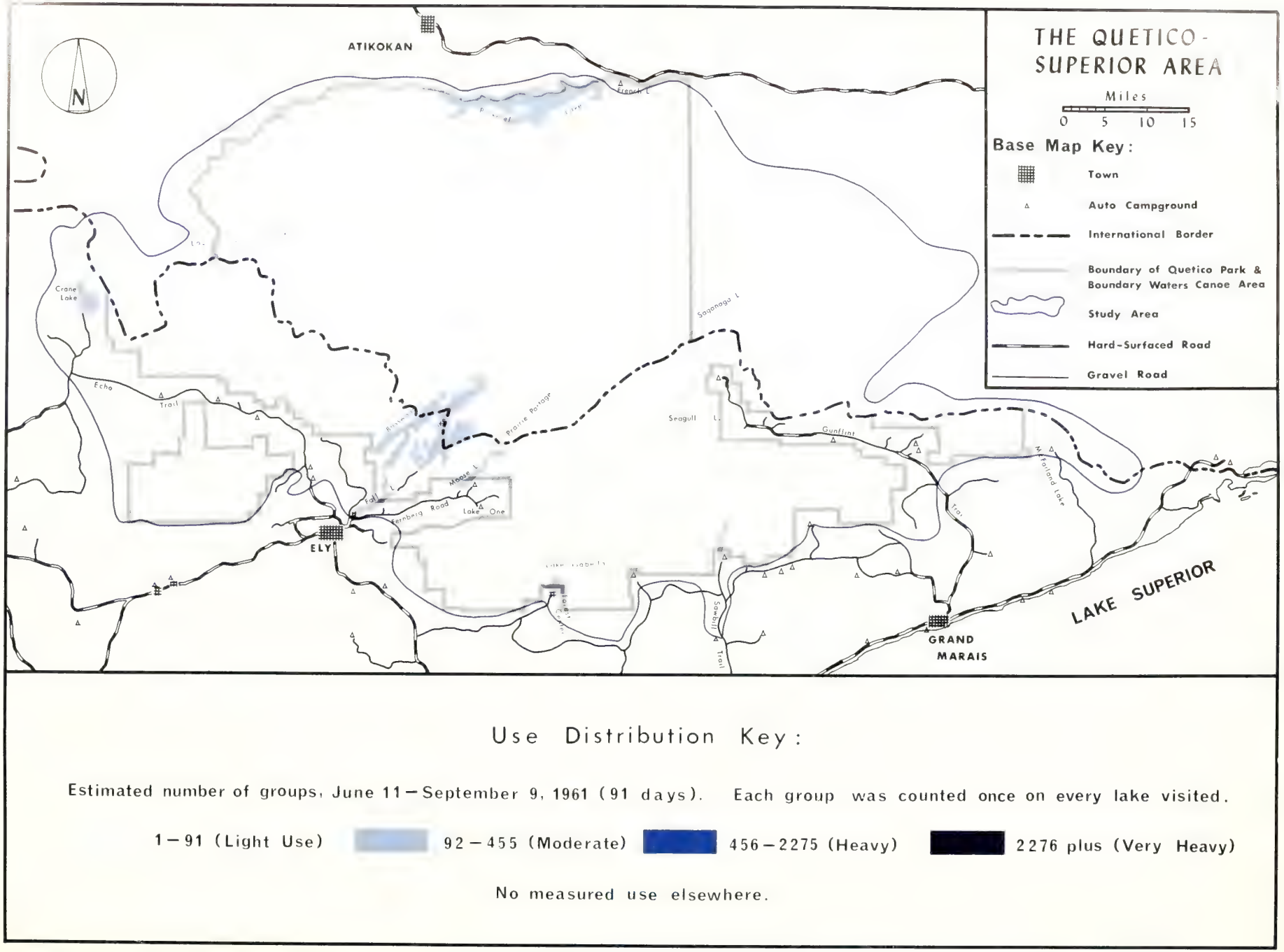


PLATE VIII. — The distribution of one-day use.

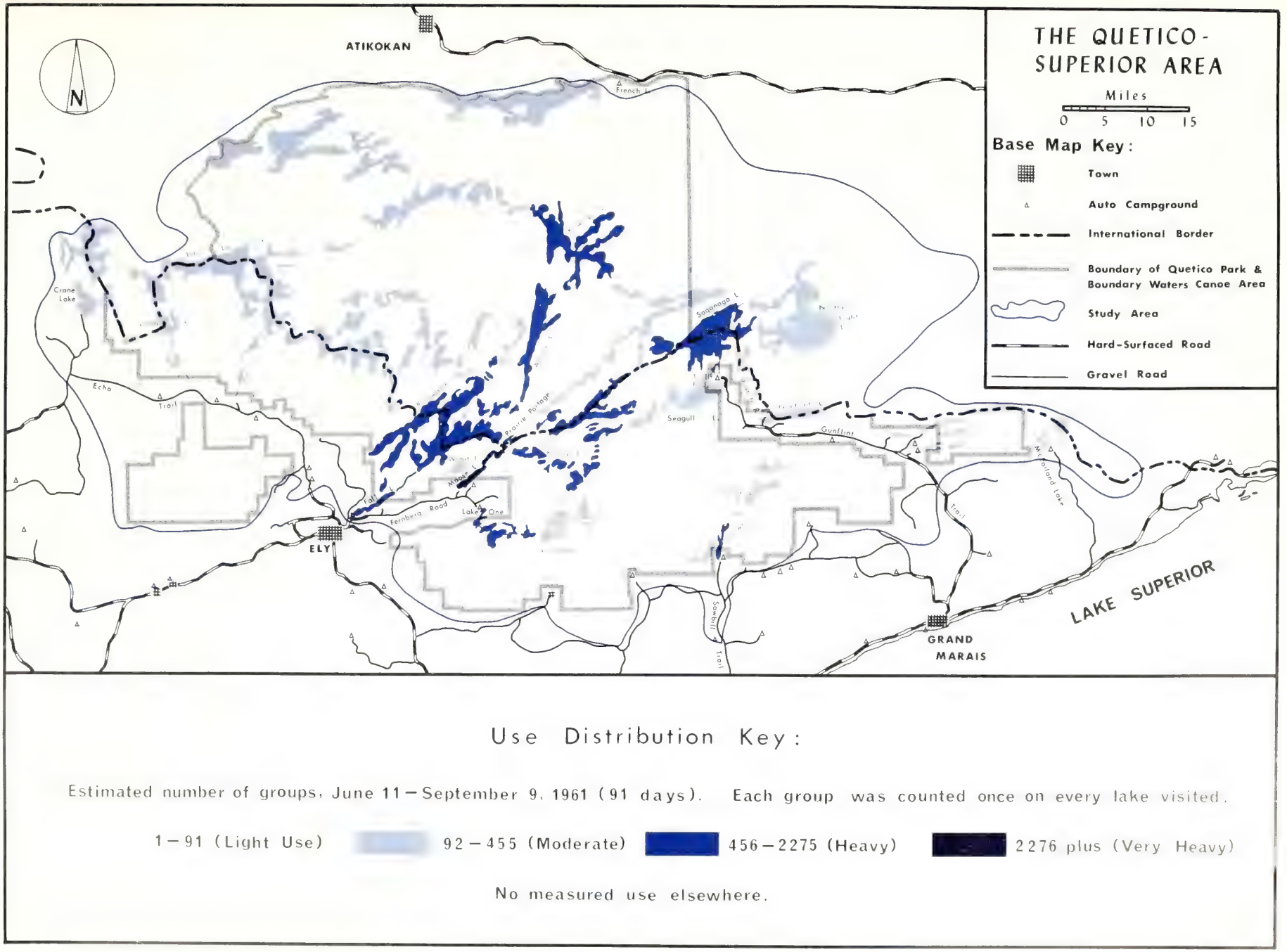


PLATE IX. The distribution of total canoe use.

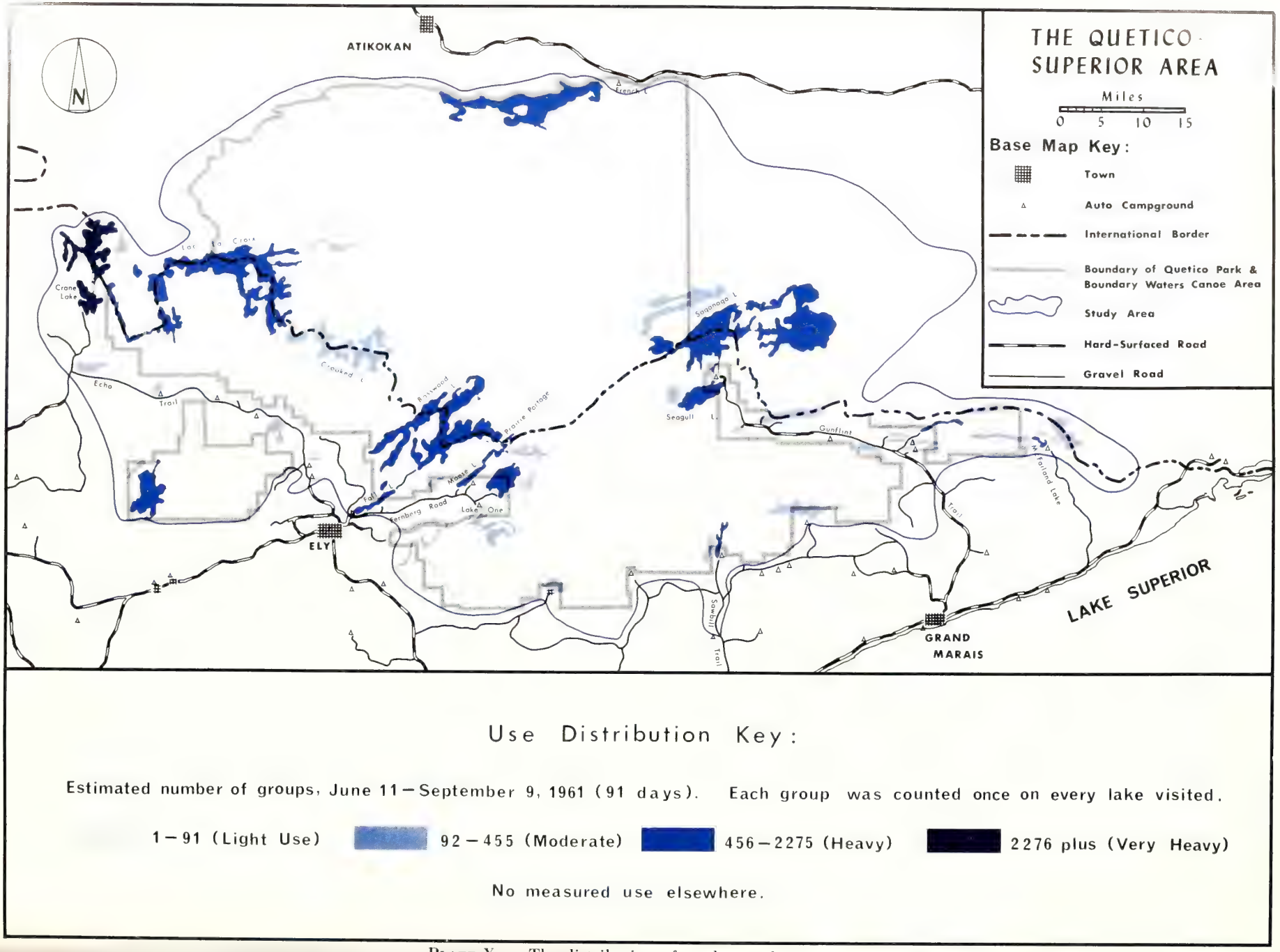


PLATE X. — The distribution of total motorboat use.

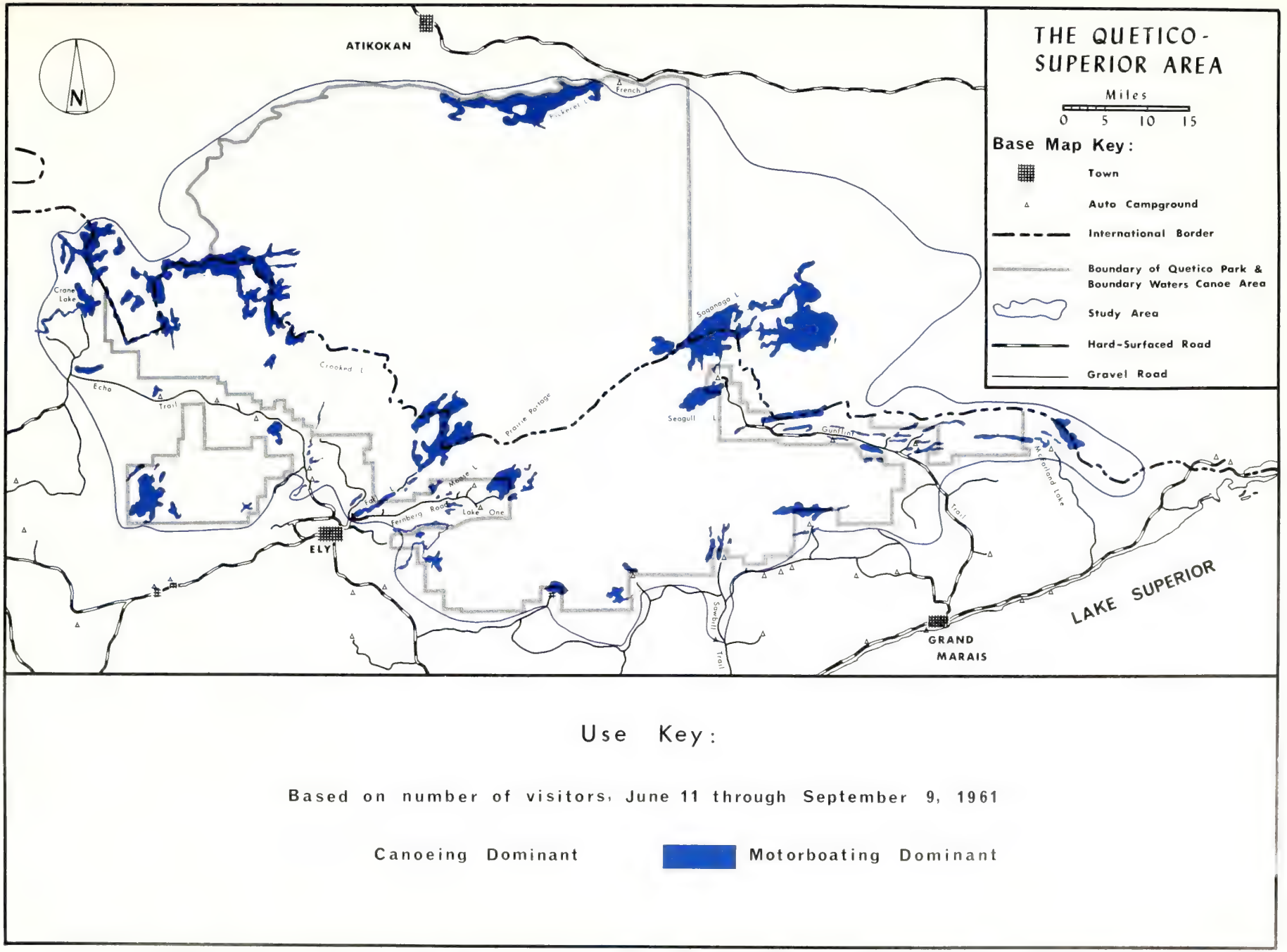
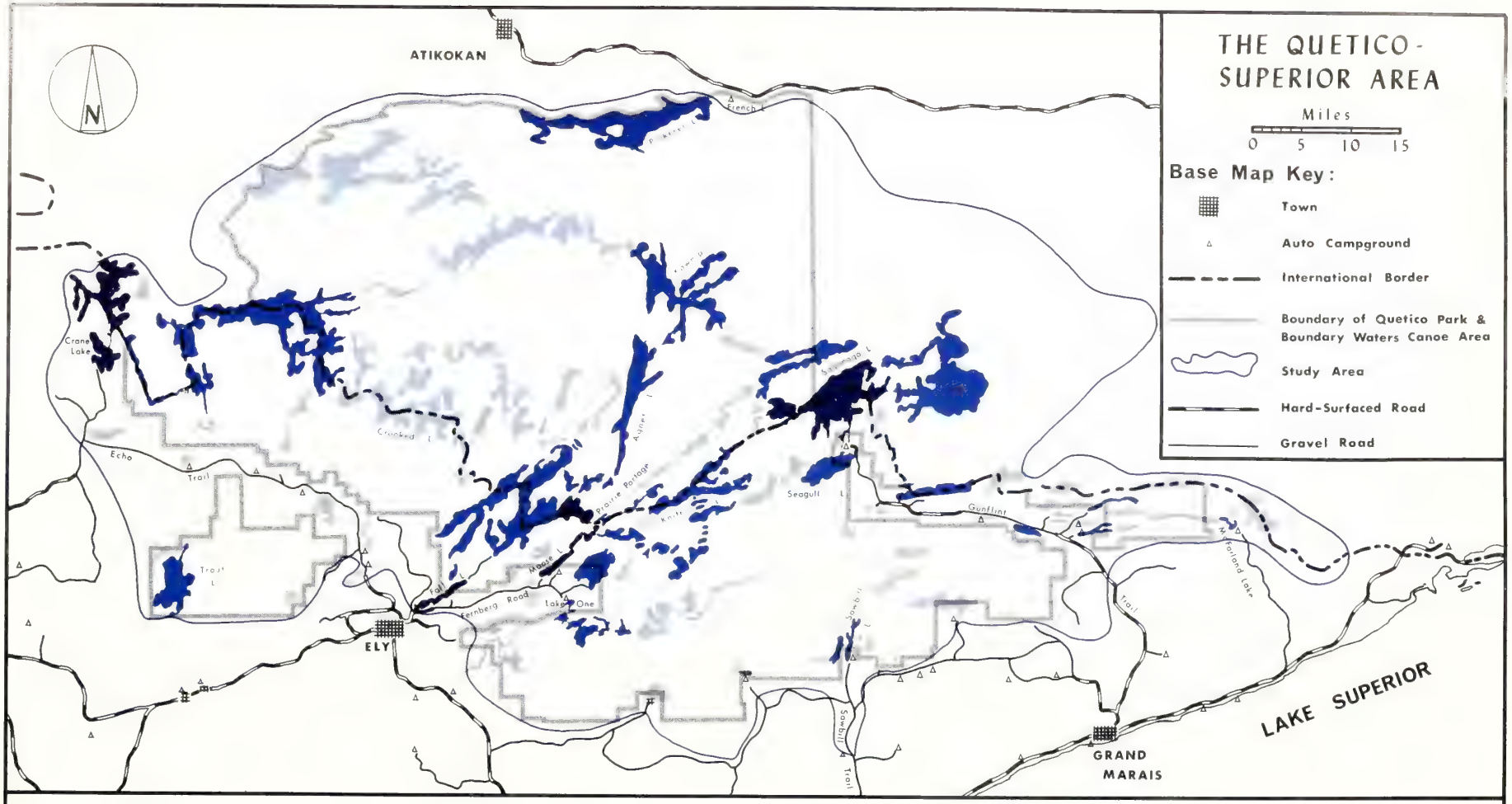


PLATE XI. - The dominant type of use (motorboating or canoeing) over the Quetico-Superior study area, 1961 study season.



Use Distribution Key:

Estimated number of groups, June 11 – September 9, 1961 (91 days). Each group was counted once on every lake visited.

1 – 91 (Light Use) | 92 – 455 (Moderate) | 456 – 2275 (Heavy) | 2276 plus (Very Heavy)

No measured use elsewhere.

PLATE XII. — The distribution of total use.

FIGURE 9. Minnesota residence classification. "S.M.A." is Standard Metropolitan Area as defined by the 1960 Census.

Even after excluding Moose Lake, the preferences for various characteristics in starting points were fairly obvious (data were organized as in Table 5 and only the major points are presented here). Starting points within a portage of Quetico Park were used much more than other places. Easy access to Canadian areas outside the Park was less important. Presence of an outfitter was positively associated with use, but of course cause and effect are intertwined: popular spots have attracted outfitters, and outfitters have helped make places popular. In decreasing order, type of water body, location on major routes, and direct access without a portage from car to lake were associated with higher use. Other things being equal, rivers were used more than lakes, and use off the major routes was negligible.

The combined qualities again emphasize the fact that a few places with almost all of the attributes had almost all the use.

For motor canoeists, as for paddlers, minimizing driving was definitely not an important consideration and neither was minimizing travel on gravel roads.

Motor canoeists' preferences were similar to those of paddlers, except for a little more use of routes which led to Canada outside Quetico.

Auto Campground Use

Much of the large range in the use of campgrounds is explained by the variation in their capacity. Campgrounds varied in average use per developed unit (campsite) from about 7 to 45 groups (see Table 4 on p. 15), whereas total use of all campgrounds varied from 20 (at Meander Lake) to 790 (at Trail's End). About half of the campgrounds apparently were used beyond capacity, if capacity is defined as the number of officially developed sites with a parking spur, table, grate, and garbage can. Lake Jeanette was used at 218 percent of capacity, and Moose Lake 177 percent; five other campgrounds were used from 100 to 125 percent of capacity.

Some of this apparent overuse may be due to errors in the estimates, but the values do not appear inconsistent with field observations.

Use was limited by capacity at many campgrounds, and it cannot be assumed that the size of the campgrounds was closely correlated with the appeal of the locations. Because the size must be considered as given, it seems more meaningful to discuss rates—groups per campsite or family unit—rather than total use.

The first factor considered, the size of the campground, did not seem to be related to the rate of use. The hypothesis that large campgrounds would be used at a higher rate, because of a chain reaction effect in word-of-mouth advertising or because people thought the large units would not be full as often as small ones, was rejected. Data showed about average use for the

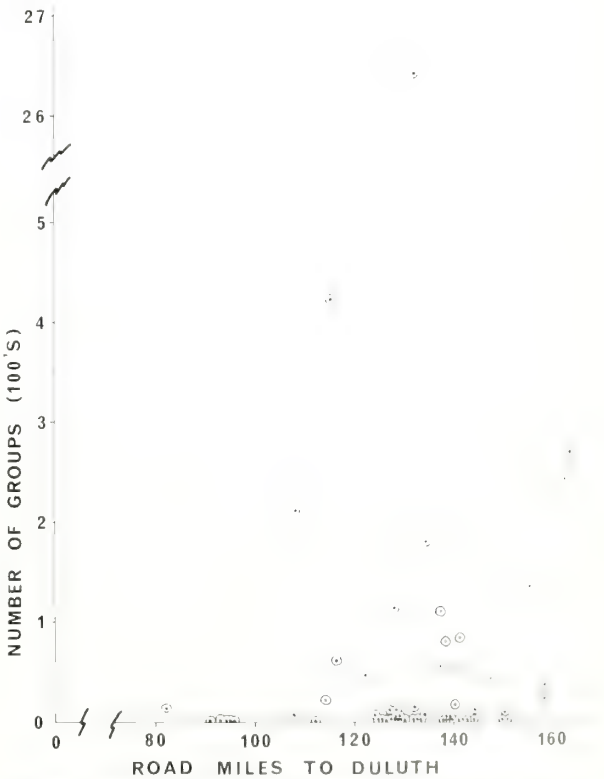


FIGURE 10. Paddling canoeist use of access points related to road miles from the points to Duluth (for access points in Minnesota only), 1961.

two largest campgrounds and very diverse use of the small ones.

None of the locational factors investigated seemed strongly associated with use. In every case the means differed in the expected direction, but the differences were small and the ranges overlapped greatly.

Only two lakes provided direct access to Canada and Quetico Park; use was very high at one and average at the other. Large lakes were more popular. Location on major routes was also positively associated with use. Campgrounds with a water supply were apparently used more. When these four factors were combined, there was much diversity and few campgrounds in each class. Small-lake locations with a water supply were used more than any other single class. All other types of small lakes, however, were used less than any type of large lake. Drinking water may have been an important consideration for small-lake locations; but within the large-lake classes, the campgrounds without water supplies had more use than those with pumps.

Four additional factors were considered, but none seemed to help in explaining the distribution. The first factor was distance from place of residence. Well over 75 percent of the groups came from south of Duluth (Table 6). Use per campsite graphed against road mileage from Duluth showed no discernible relationship, however, and scatter was extreme. The number of miles of gravel road from the campground to a paved highway also showed no relation to use.

There was little support for the hypothesis that an isolated solitary campground tended to have a lower rate of use than a cluster of campgrounds (because of less overflow, and perhaps because of less visitor confidence in finding a place where only one campground was available.) Again, scatter was extreme, but the average rate for campgrounds within 6 miles of their nearest neighbor (by road) was 24 groups per campsite compared to 17 for those 8 to 18 miles apart. However, the two most isolated campgrounds, both apparently very popular, averaged 36. These two were both very small (only two and three campsites), and use estimates for both were based upon a sampling rate half that of almost all of the other campgrounds.

Finally, the campgrounds were grouped by roads. The ranges of use overlapped greatly (Table 7). The only campground on the McFarland Road had the highest average—37 groups per campsite. The Fernberg Road was next most popular, and this, of course, was due to Moose Lake, as Lake One was about average. The Gunflint Trail had by far the greatest total use, and all of its campgrounds were used substantially. On the Echo Trail, Lake Jeanette, the campground nearest Crane Lake, compensated for three campgrounds with below-average use. The Sawbill area varied from high to low.

TABLE 7. — *Amount and rate of campground use by major roads, June 11 through Sept. 9, 1961*[1]

Road	Number of campgrounds	Total groups	Groups per campsite	
			Average	Range of averages
Echo Trail	4	530	18	7-45
Fernberg	2	370	33	20-45
Sawbill Trail	3	660	21	10-35
Gunflint Trail	4	1,310	22	17-28
McFarland	1	110	37	-

1/ Data taken from roadside interviews. Nels and Fall Lakes were omitted because neither had developed camping units.

In summary, campground use did not seem to be very predictable on the basis of campground characteristics. There are at least four possible reasons for the uncertainty which surrounds almost every hypothesis examined. One, the data may be inaccurate. This is most serious for the small, lightly used campgrounds because of small samples. It seems questionable, however, whether even a fairly large random error or an over-all bias (and there is no reason to believe a bias exists *between* estimates for different campgrounds) would so obscure any strong relationships. Second, the factors investigated may not be the right ones. Perhaps a reputation as a good fishing lake was more important, but this information was lacking. Third, most of the hypotheses rest upon an assumption that people desired to minimize cost or effort and preferred improvements—or possibly upon just the reverse, that they desired to maximize cost or effort by going to the end of the road or getting away from improvements. If people here had behaved fairly consistently in either of these ways use would have been more predictable. However, these two forms of behavior were apparently very mixed; some people wanted to rough it in the most isolated campground, and others did not. A later publication will show how conflicting were the attitudes of visitors in general, particularly for auto campers. A fourth major reason is that many people did not really make a choice, either because they were unaware of alternatives or because their first-choice campground was already full.

Boat Camping Use

Of the 64 possible access points,[8] 36 were used by sample boat camping groups. These 64 points averaged

[8] *Two more than for canoeists. Several lakes with no portages to waters beyond and therefore not on canoe routes are included, and small rivers not usable by boats are excluded.*

58 groups; but the variation was great. Excluding unused points, use ranged from 2 to over 900 groups and averaged 102 groups.

The most highly related single factor was location accessible to Canada without a portage. Quetico Park entry points seemed less important than Canadian water in general, mainly because of Crane Lake's great popularity for boating. Almost 90 percent of the Crane Lake boat campers went to Canada, but less than half went east over the rail portages to Lac La Croix, part of which is in Quetico Park. Next most related was type of waterbody, followed by location on a major route, and then by direct access from car to lake.

The grouped factors suggest that border location was overwhelmingly important. All other types of locations had much less use, except Trout Lake, an 8-mile-long lake in the southern part of the Boundary Waters Canoe Area, where a truck hauled in large numbers of boat campers. Although use at locations away from the border was low, the progression between classes of locations was quite regular; additional favorable factors were usually associated with more use.

Additional driving distance clearly was not associated with declining boat camper use. This also held for distance over gravel roads.

Resort Use

Resort use can probably be analyzed better in terms of absolute numbers of groups rather than as an average per resort or per cabin. First there was more excess capacity (Sielaff 1959, Table 17 and pp. 14-16; and personal observation) so that an upper limit on use had less meaning than in campground use. Second, the supply presumably has tended to increase where demand has been greatest,[9] because resort services are marketed for profit. Only rough estimates of resort capacity were available, but the proportion of capacity utilized apparently varied less from lake to lake than did that for campgrounds. Differences in rate of utilization as related to resort quality tended to even out between lakes because most lakes had a number of establishments. Lakes without resorts were excluded as it was almost impossible to determine which ones could not have resorts because of a combination of landownership and policies (public and private). The last argument also holds for private cabins.

Resorts on water routes without a portage to Quetico Park entry points had the greatest use. Next were resorts with direct routes to any Canadian waters. Resorts on large lakes had considerably more use than those on small ones. So did resorts on major routes compared to those not on major routes.

The combined factors tended to support the conclusion that these four qualities were related to use.

In general then, the distribution of resort use seemed more predictable than that of campground use. Resort guests seemed more homogeneous in their decisions and agreed better as to what sorts of resort locations were preferable—large lakes, lakes with good opportunities to go back another lake or two, and direct water routes to Canada, especially to Quetico Park. The most desirable lakes in these terms often required more driving, and more travel on gravel roads, both of which the resort guests did, either as a price they were willing to pay or because going to the end of the road had intrinsic appeal around a roadless area.

Private Cabin Use

Again, total use of cabins seems particularly appropriate for analysis because most individuals have chosen the cabin's location, not selected from a limited number of existing locations, such as campgrounds. However, because 73 cabins inside the Boundary Waters Canoe Area have been eliminated through purchase, and the remaining cabins cannot expand capacity as the comparable resorts have, the analysis is limited to cabins on lakes at least partly outside the Canoe Area.

When characteristics were grouped, the over-all relationships were less clear than for resort guests. The greatest use was on the large lakes on major routes to Canada, regardless of whether or not to Quetico Park. Next came large lakes on major routes. Other large lakes did not seem to be preferred over small lakes.

Cabin use as related to remoteness showed much scatter with perhaps a weak tendency for use to *rise* with increasing distance. Miles of gravel road in relation to use showed even more scatter and no trend.

One-Day Use

One-day use occurred at 28 locations, which averaged 72 groups each. The distribution was more even than the distributions for other types of lake use.

[9] *This applies to the fringe area outside the Boundary Waters Canoe Area, not within it where public policy has curtailed the supply of resort accommodations. However, the three lakes completely inside the Boundary Waters Canoe Area with bona fide resorts (Lac La Croix, Crooked Lake, and Basswood Lake) still averaged over 400 groups compared to an over-all average of 230, and they are included in the analysis. By early 1963, 33 resorts had been removed, mainly from Basswood Lake. Total use was probably even higher before, although the remaining resorts have enlarged and probably enjoy a higher rate of use in their present semi-monopolistic situation.*

Of these groups, 44 percent were made up of people living in the local area; 30 percent more lived nearby in other northeastern Minnesota areas (see Table 6 and Fig. 9). The proximity of local population seemed to be the main factor associated with the distribution of 1-day use. Fall lake, 5 or 10 minutes from Ely, had the most 1-day use, about 350 groups. Forest Center, a small logging settlement, is located almost on the shores of Lake Isabella where residents kept boats on the beach, and something over 250 groups are estimated to have used the lake. Pickerel Lake, near the mining town of Atikokan, Ontario, was next. Crane Lake, accessible to the settlements on the Mesabi Iron Range, followed closely. Locations farther east, especially on the Gunflint Trail, where local populations were small and distant, had very little 1-day use. This was also true of places near the end of the Fernberg Road or along the Echo Trail. Although it is difficult to measure relative remoteness objectively for 1-day use, because of the spread of residence of these people, apparently parties with only one day to spend tried to spend as much of it on the lakes as possible.

Places requiring a portage to a lake or river had only about 5 percent of all 1-day use, most likely because this use was essentially all boat use, and hauling a boat over a portage for an afternoon's fishing was viewed as a poor bargain.

Large lakes were much more popular. Location relative to Canada had little or no association with use.

Summary of Factors Related to Use of Starting Points

To summarize, there seemed to be four types of distributional associations. Canoeists were most predictable; starting points on large lakes leading to Quetico Park were most attractive to them. Canoeists also used access points requiring a portage from car to water more than did boaters. Auto camping was not strongly related to the locational characteristics investigated. The preferences of the other types of visitors were similar and fairly predictable; heaviest use for these types (primarily boaters) was on large lakes with starting points directly on waters leading to the Canadian border. Day use was mainly associated with accessibility to local populations.

Factors Related to Use of Water Routes

In this section the rate of decline in use of routes, as portages became more and more numerous and more difficult, is discussed first. Then, some factors related to popularity of some particular routes are considered.

The relationships are very different for boaters than for canoeists. There was some difference between canoeists who paddled and those using outboard motors.

Canoe Use[10]

Portages were related much less to canoe use than to boat use. About 95 percent of the canoeists portaged at least once, but a single unmechanized portage stopped about 80 percent of the motorboaters (Fig. 11).

The youth camp groups portaged much more than other paddlers. The curve for a small sample of Boy Scouts is horizontal for most of the range shown on the graph; this was typical of all of the camps. Camp groups were a small part of total use, but they spread a veneer of use over almost all of the more remote lakes. The amount of use by other paddlers declined regularly and gradually, almost in a straight line. Over 50 percent of all of the paddling groups crossed at least 5 portages before they turned back toward their starting point. Motorized canoe use still differed considerably from paddling use (even excluding camp use); 8 portages away from the starting point 30 percent of the paddlers but only 13 percent of the canoeists with motors were still around.

Four factors seemed to account for the paddlers' greater range. First, although a motor permitted faster travel over water, more paraphernalia was required—motors weighing 20 to 40 pounds and heavy gas cans—which made portages more of a chore. The slower water travel by the paddlers did not significantly limit their range, given the scale of the study area. Enthusiasts could paddle clear across it anywhere in less than a week. A second reason lay in the different motivations of the two groups. The paddlers looked upon the canoe travel itself as a major objective, and cruised widely for its own sake, to explore the country, and to get away from other people. More of the motor canoeists were interested primarily in fishing, and considered canoe travel as a means to get quickly to a good place to fish; they had no strong desire to go beyond a lake which they thought was not "fished out." A third factor, probably related to motivation, was that motor canoeists tended to be older. Only 42 percent were under 20 compared to 64 percent of the paddlers, and 21 percent were 35 or older compared to 16 percent of the paddlers. Fourthly, the average paddling canoe group (omitting youth camp groups) stayed longer: 7.1 days compared to 5.7 days for motor canoeists. Youth camp groups stayed longer yet, 8.6 days.

[10] *Canoeing incidental to auto camping, and so on, is excluded.*

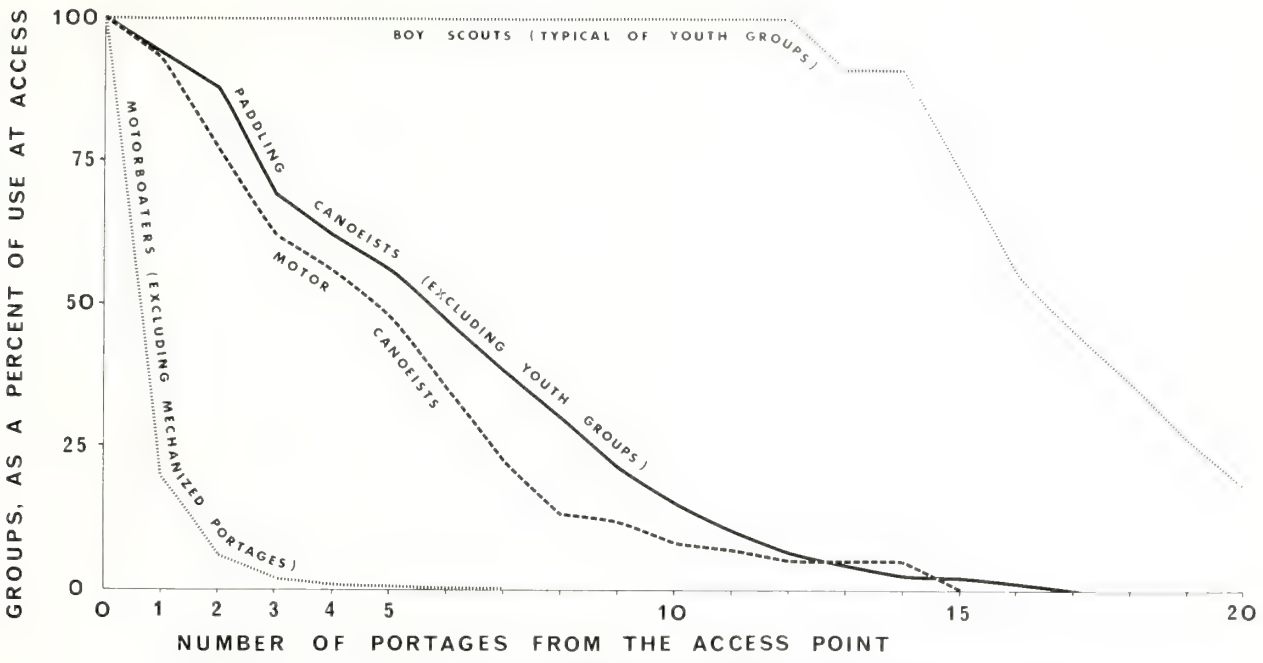


FIGURE 11. — The amount of selected types of use related to the number of portages from the access point to the location, 1960 and 1961.

Portages apparently had a different meaning for canoeists than for boaters. Boaters, as is discussed in the following section, seemed to consider lakes as a goal and portages as a cost. The situation was very different for canoeists, especially for the paddlers. They seldom had a definite lake as a goal, and portages were just another part of the experience. It is not appropriate, therefore, to interpret Figure 11 primarily as the result of a filtering-out process due to portages. The curve declines with increasing portages more because people ran out of time and turned back than because portaging was such a burden. This means that distance from an access point was more highly related to canoe use than was number of portages. If this is true, the maps of canoe use should be more nearly concentric around accesses than is the boat use map. Although there are exceptions, the canoe use maps *are* reasonably concentric in this way, and much more so than the boat maps. This is another case where technological advances in transportation apparently narrowed the choice of ways.

The decline in canoeist use away from access points is best described by the map, Plate IX. It integrates the effect of the number and difficulty of portages, size of lakes, frequency of distributary routes, and overlapping of routes as they actually occur in unique combinations over the area. This seems to be the research tool that would aid an administrator most in deciding how many canoeists he should allow to enter at an existing access point if he felt that use on certain interior lakes should be limited to some particular level. Although boat use is much simpler in pattern, that map (Plate X) is also the most accurate guide for administrative decisions. However, the relation of portages to use (Fig. 11) helps in predicting the consequences of any additional access.

Mechanized portages had little significance for canoeists. The most heavily used portages were not mechanized, and even where such aids existed, as between Loon Lake and Lac La Croix, many canoeists carried around them anyway.

Length of portages had some relation to use, more for motor canoeists than for paddlers (Table 8). Motor canoeists were similar to boaters in percentage of portages used. The average numbers using longer portages declined more for canoeists than for boaters, but the practice of boat storage (discussed below) was probably the explanation.

What factors help explain the choices of routes shown on the canoeist maps? For both types of canoeists, outfitter's advice was the main reason cited (Table 9). Between 25 and 30 percent of the canoeist groups had no previous experience in the area, and almost all of those gave this reason. Professional guides played a very minor role. Except for the groups from young people's camps, none of the sample paddling canoeists used guides, and less than 10 percent of the motor canoeists hired a guide.

Word-of-mouth advertising was important for both groups, and so was previous experience. Scenery was not often cited as decisive. Easy routes and good fish-

TABLE 8. — *Use of portages[1] related to portage length for three user types*

Item	Length of portages		
	1/4 mile or less	Between 1/4 & 1/2 mile	Over 1/2 mile
Percent of portages used by:			
Paddling canoeists	89	89	67
Motor canoeists	42	68	33
Motorboaters[2]	49	45	30
Average number[3] of groups using portages for:			
Paddling canoeists	119	79	35
Motor canoeists	82	28	36
Motorboaters[2]	105	95	51

1/ The first portages on each route were taken as representative.
2/ Unmechanized portages only.
3/ Average for portages that were used; unused portages omitted.

TABLE 9. — *Frequency of various reasons for choice of route cited by canoeists*[1]

Reason for choice of route	Percent of total	
	Paddlers (64 groups)	Motorized (21 groups)
Recommended by an outfitter or guide	39	43
Recommended by a friend or acquaintance	25	19
Have started here before, know the route	22	24
More attractive scenery than other routes	3	5
Fewer or shorter portages than other routes	5	14
Better fishing than other routes	5	14
Easy way to get to Canada	0	0
Meet fewer people here than on other routes	17	5
Have not gone this way before, something new	11	19
Other	11	5
None, don't know	0	0

1/ Data from long interviews. Percentages add to more than 100 because many groups cited more than one reason.

ing were cited three times more often by motorized canoeists than by paddlers, which was consistent with other findings. In contrast, lack of crowds was much more important to paddlers, and again this conformed to other data. Novelty of a new route was also commonly mentioned, especially by motor canoeists. None of the canoeists said they did not know why they had chosen their route.

When asked specifically about Canada, no canoeists listed it as a factor in choice of route. This was surprising in view of earlier conclusions. Perhaps the question was faulty, or again, canoeists may have gone to Canada to enjoy qualities they thought it had, rather than because it was Canada. When asked why they had gone to Canada, most canoeists were vague. Over half of the paddlers said, "We always go to Canada." or, "To say we'd been there," and one third could give no reason. Fifteen percent said they chose Canada because it was wilder, and 7 percent said because fishing was better. The motorized canoeists were clearer; half said they went to Canada because they thought the fishing was better.

Generally, canoeists visiting Canada discovered few differences from the U. S. side. Two thirds found no differences, and 10 to 15 percent said Canada was wilder or had "bigger trees," fewer motorboats, or fewer users.

The Canadian border seems to have had little effect as a barrier. Most of the canoeists on the border lakes crossed into Canada. The border seemed to attract rather than repel; only about 17 percent of all canoe groups that avoided Canada said they did so because of expense or regulations.

The physical pattern of the lakes was also related to use. For example, the route from Lake One east had no side routes of any magnitude until after Lake Insula, and use declined little even after six portages. In contrast, from Moose Lake three major routes diverged near Prairie Portage, and a fourth secondary route went through Wind Lake; as a result, the stream of canoeists spread out faster and use on each route declined fairly fast.

Apparently routes to the north tended to be favored, especially by paddlers. From Saganaga more groups headed north to Kawnipi than southwest on the border or east to Northern Light Lake. From Gunflint Lake more canoed north on the Granite River than east on the border. From Moose Lake the least used route (after the Wind Lake short cut to Basswood) was the route to the east through Ensign Lake. Even at Sawbill Lake, remote from Canada, the most used of three main routes was north to Cherokee Lake.

Boat Use

As pointed out previously, most motorboaters used the portages and water routes in very much the same ways whether they were staying at resorts, cabins, campgrounds, or camping out on the lakes. This similarity was due to two things primarily: the restricted mobility of boats, and similar motivations for all those using boats, regardless of visitor type. Because of this

similarity, total motorboat use (Plate X) is analyzed rather than the maps of each type of use.

The amount of use was related more to number of portages[11] than to distance from access points. Within the study area 33 lakes and 3 rivers usable by boats could be reached directly by car, and 6 more lakes could be reached by boat without a portage. All but three of these locations were used by people in motorboats during the study period, with an average of 520 groups on each. Unmechanized portages reduced use greatly, however (Fig. 11). Only about 45 percent of the lakes that conceivably could have been reached by one foot portage were used, and an average of only 90 groups used such lakes.

Many of the unmechanized portages still did not require carrying or dragging a boat over the trail. Resorts in particular stored boats over many (probably more than half) of the portages, sometimes as far as two or three portages back, which greatly reduced the significance of portage.

Where portages were mechanized, use declined much less; in fact, the 6 lakes reached by one mechanized portage had almost as many total visitors as all 54 lakes reached by one unmechanized portage. These six lakes averaged 680 groups each, which is more than the average of directly accessible lakes. Most of the six were large, desirable lakes, or a step along the way to such lakes. Mechanization apparently seemed worthwhile only for these large lakes. Lac La Croix was reached by two mechanized portages, and over 1,000 motorboating groups visited it. The resort on Crooked Lake used jeeps on two portages beyond La Croix, and an estimated 125 groups stayed at this resort. Boats were not hauled for the general public on these last two portages, however.

Since the amount of boat use was more a function of number and type of portages than of distance, the decline in the amount of use away from access points was not even roughly concentric. The size and shape of the lakes resulted in axes, or fingers, along which use declined slowly and by steps. This describes use on routes originating at Crane Lake, Fall Lake, Moose Lake, and Saganaga, for example, where there were long, large lakes separated by only one or two portages. In other directions, where more portages were encountered sooner and lakes were smaller and less appealing to boaters, use decreased abruptly. Examples are routes reaching south and west of the Gunflint Trail, and on either side of the Echo Trail.

The eastern slate area, on the other hand, was almost all used by motorboats, because of the ready-made routes provided by the elongated parallel lakes.

The Canadian border, with the drawbacks of customs declarations, a duty on food (except on Basswood Lake), $5 boat and canoe tags, travel permits, and nonresident fishing licenses, did not seem to deflect motorboat routes. On the four major international lakes where border control was maintained, 74 percent of the interviewed groups said they had entered Canada. This was consistent with the strong attraction of Canada revealed previously.

Examination of Table 10, showing reasons for choice of route, indicates that not much choice was exercised.[12] This aimlessness has a bearing on policy implications, which will be taken up in a later paper. The most frequent response for all groups except the boat campers was "no reason" or "don't know." In sharp contrast, canoeists never reported "no reason." Recommendations of outfitters, resort operators, and guides were insignificant except for resort guests (about 40 percent of the resort guests used guides—nobody else did). Information from friends had some effect, particularly for auto campers. Familiarity was cited by almost three fourths of the boat campers, and many of the others. Scenery was mentioned fairly often. Easy portages were cited only by boat campers and private cabin users, which is probably at least partly due to the resorts' practice of storing boats for their customers' use. Fishing was a major factor in decision making for all except auto campers. Lack of people was minor but most important to boat campers, as would be expected.

Canada was rarely mentioned directly despite its strong apparent relation to use. Those who went to Canada were asked why they had, and over half (57 percent) said they had no reason, it was just "something to do." Good fishing was cited by 39 percent.

Again, it is interesting to compare people's experience in Canada to their expectations. No difference was detected by 71 percent of these people and differences such as bigger trees in Canada, better scenery, wilder country, and more fish were each reported by only 3 to 10 percent of the groups.

Inspection of Plate X does not suggest a strong tendency to prefer travel towards the "romantic, wild north," although the few natural motorboat routes on large lakes leading south provided little basis for judgment. Where the degree of difficulty and the character

[11] *Portages could not be shown on the small-scale use maps. The large-scale Fisher maps cited are the best source of portage information for the entire area.*

[12] *Professor Philip M. Raup of the Department of Agricultural Economics, University of Minnesota, has pointed out the similarity to "impulse buying."*

TABLE 10. — *Frequency of various reasons cited for choice of route by users other than canoeists*[1]

Reason for choice of route	Percent of total groups			
	Auto campers (96 groups)	Boat campers (24 groups)	Resort guests (57 groups)	Private cabin users (21 groups)
Recommended by an outfitter or guide	6	0	18	0
Recommended by a friend or acquaintance	27	5	13	0
Have started here before, know the route	18	71	36	42
More attractive scenery than other routes	3	14	8	16
Fewer or shorter portages than other routes	0	14	0	8
Better fishing than other routes	3	24	26	33
Easy way to get to Canada	0	5	3	0
Met fewer people here than on other routes	3	14	5	8
Have not gone this way before, something new	3	0	13	0
Other	18	19	8	33
None, don't know	27	14	38	42

1/ Data from long interviews. Percentages add to more than 100 because many groups cited more than one reason.

of the lake at the destination were similar, boaters seemed to go one direction about as willingly as another.

Summary of Factors Related to Use of Water Routes

In summary, the type of craft and kind of power were the deciding factors for the use of routes by all classes of visitors. Boaters used mechanized portages heavily, but used other portages lightly. Paddlers, especially from young people's camps, ranged most widely. Putting a motor on a canoe seemed to be associated with a somewhat narrower range, and the length of portages had the greatest depressing effect on amount of use. For boaters, portages affected use more than distance over waterways, but the opposite was true of canoeists.

TRENDS IN RECREATIONAL USE

There has been much interest the last few years in assessing past trends in amounts of outdoor recreation activity and in projecting these trends into the future (Clawson and others 1960; U. S. Forest Service 1959; Outdoor Recreation Resources Review Commission 1962b; U. S. Senate Select Committee on National Water Resources 1960; Wildland Research Center 1962; Zivnuska and Shideler 1957). None of these efforts can be considered entirely satisfactory for two main reasons, both of which also present difficulties in the Quetico-Superior Area.

Past use records are short and inaccurate. Quetico Park figures began in 1951, and the figures based on compulsory travel permits go back only to 1955. Statistics for the Boundary Waters Canoe Area (and its predecessors under various names) began in 1946, but until 1960 estimates were based mainly upon reported numbers of customers for outfitters and resorts. As a result the totals may be considerably in error, and changes from year to year are sometimes erratic because of different people making the estimates. Estimates of man-days fluctuated even more than estimates

of visits, because of an almost complete lack of data on length of stay.

Linear projections of these inadequate past histories are questionable. An alternative would involve using the relationships between participation in various sorts of outdoor recreation and other characteristics of society. This approach has promise since data and projections are more readily available for many of the presumably significant variables. Several studies have broken this ground recently.

The first social variables considered in recreation projections were population, income, leisure time, and mobility. Indices of projected changes in these factors were combined by multiplication in the earlier studies (U. S. Forest Service 1959, pp. 23-36; Clawson 1959a, b). In 20th Century America it seems certain that income, leisure, mobility, and population are interdependent, however, and some of these variables may be largely redundant. In fact, the Wildland Research Center (1962, pp. 225-243) used per-capita income alone, and Zivnuska and Shideler (1957) used only population. It also seems unlikely that the variables are simply multiplicative; furthermore, other factors also play a role. Education and tastes are two possible additional variables; again, these are probably interdependent. Another element is undoubtedly supply; this helps to explain the slower increase in State Park use than National Forest use as well as the decline in duck hunters. The Outdoor Recreation Resources Review Commission (1962b, esp. pp. 11-22) used seven factors: family income, education, occupation, place of residence, age-sex, leisure, and an opportunity or supply factor (actually two alternative assumptions about supply). Assumptions about the amount and accessibility of supply are awkward to use in projections made to guide policy decisions about how much outdoor recreation to supply, because of the inevitable circularity.

Given this array of difficulties, what do we know that will help us project trends in the use of the Boundary Waters Canoe Area?

Total Visits

The increase in estimated use of the Boundary Waters Canoe Area has been substantial and quite steady (Fig. 12). The occasional periods of leveling off may partly reflect concern that previous estimates were exaggerated; the one exception is the period of dissension at the time of the air ban in 1949. The average rate of increase per year[13] from 1946 through

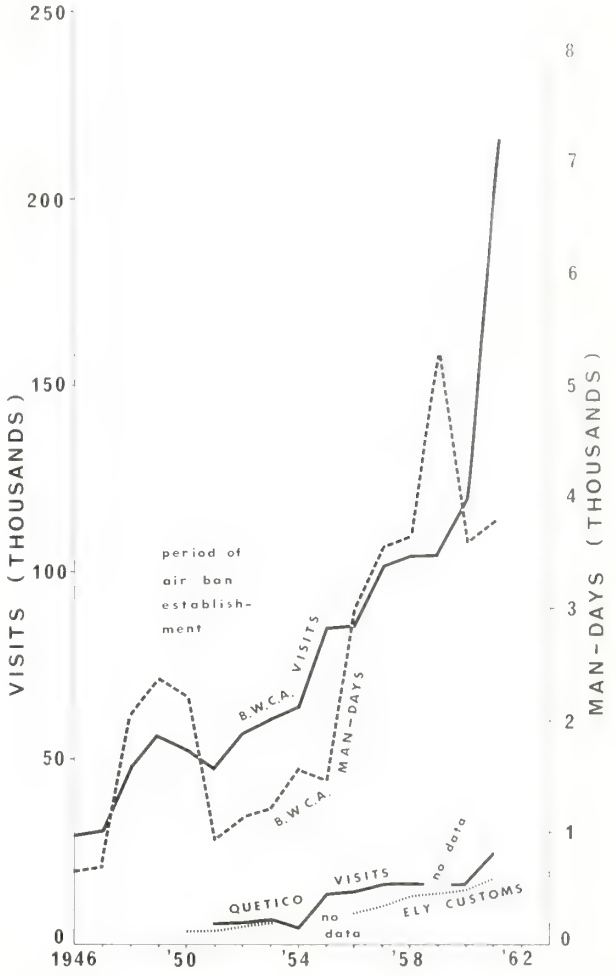


FIGURE 12. — Estimated increase in use of the Boundary Waters Canoe Area and Quetico Park, and U. S. Customs entries at Ely.

1960 was 12 percent. This equals the rate for total recreational visits to all National Forests. The data for 1961 and 1962 show a much more rapid growth, but part of this is due to more accurate estimates based on methods used in this study.

The Forest Service has developed projections of total visits for the Boundary Waters Canoe Area, using the system described above. According to these unpublished figures, by 1976 visits would rise to 319,000, an increase of 207 percent over 1959. By 2000 there would be 785,000 visits in search of solitude, 655 percent more than in 1959. These projections were made before the estimated number of visits was doubled in accord with the survey findings. To fulfill these projections, which may seem high at first glance, the average annual increase in visits would only need to be half what it has been over the last 15 years, figuring from the 1959 base of 104,000 visits.

[13] *Computed by adding the annual percentage increases and dividing the sum by the number of years in the series.*

The Wildland Research Center (1962, p. 236) predicted a 239-percent increase from 1959 to 1976 in man-days spent in the Canoe Area, and a 706-percent rise by 2000. The estimates, both by the Forest Service and by the Wildland Research Center, suggest much faster growth in use of the Boundary Waters than for outdoor recreation in general. All outdoor recreation activities were predicted to increase 58 percent from 1960 to 1976 and 184 percent by 2000 (Outdoor Recreation Resources Rev. Comn. 1962b, p. 22). General camping and boating (other than canoeing and sailing) were predicted to increase only about a third as fast as use of the Boundary Waters Canoe Area.

Quetico Park has had a large increase as well, almost doubling from 1955 to 1961—an average of 13 percent a year during this period (Fig. 12). The figures for 1951-1955 are from voluntary travel permits and are not reliable or comparable with the compulsory permits used after 1955.

Use by Types of Recreationists

The various types of recreationists appear to be distinct and independent. Few individuals shift from one sort of recreation to another except the motor canoeists, a majority of whom have had experience paddling a canoe. This finding (lack of shifting) should be tested in other regions. It contradicts the common local idea that most people progress from resort to campground to canoe trip, "building up courage."

In the long interviews, groups were asked about the nature and amount of their previous experience in the area. If one person in the group had switched types, this was counted so that stability of type of recreation for individuals was still greater than that reported for groups.

The data show several interesting features (Table 11). Paddling canoeists and resort guests were both very definite in their choices, and private cabin users were almost as set in their ways. Motorized canoeists, who were local people more often than were paddlers, were very faithful canoeists; no one in the sample had ever done anything but canoe, although they did switch from paddles to motors. Auto campers and boat campers both had a fair amount of previous experience along many other lines, with two exceptions: neither had used private cabins to any extent, and neither group had done much of the other type of camping. In past research these two camping groups have been combined (Taves and others 1960), but they are distinct. Neither sort of camping is done often by non-camping groups. No canoeists had ever gone boat camping, and few had used auto camps. The hostility of many resort operators to free public campgrounds also seems to have a rather limited basis in this area. Resort guests had almost never camped; and only 22 percent of the auto camper groups had ever used resorts in the area and about half of those had stayed at resorts only once.

Young people's camps have had a strong effect upon the formation of tastes. Of the total sample of 292 groups, 38 had some members who said they came to the area originally as campers at one of the organ-

TABLE 11. — *Amount and type of previous experience in the Quetico-Superior area, for groups*[1]

Type of recreation group	No. of groups sampled	Percent of groups with previous experience in area	Percent of groups with previous experience by type of previous experience						
			Paddle canoe	Motor canoe	Resort	Private cabin	Auto camp	Boat camp	Young people's camps[2]
Paddling canoeists	64	73	91	4	15	2	9	0	52
Motor canoeists	21	71	73	60	0	0	0	0	14
Resort guests	57	84	2	0	94	2	6	2	17
Private cabin users	21	100	14	10	19	81	10	14	10
Auto campers	96	78	22	14	22	5	75	9	7
Boat campers	24	96	22	26	26	0	0	87	0
Day users	9	78	17	50	0	0	0	33	0

1/ A group was considered as having previous experience in the area if even one member had visited the area previously. Data are from long interviews. Data on each line do not add to 100 percent because some groups had had previous experience in two or more categories.

2/ Parties with members who came to the area originally through one of the young people's camps, such as Boy Scouts, YMCA, or private camps.

ization or private camps, and two thirds of these groups were paddling canoeists. Every youth camp in the area builds its program around this type of canoe trip and vigorously inculcates a set of values rating paddling very highly. Since many of these former campers are aging, have married women uninterested in canoe trips, accumulated children, and acquired friends without their own biases, the two-thirds figure seems very high.

Trends in use for each of these types are very poorly understood. Official statistics are not yet detailed enough to be broken down by types of recreationists. Very generally, it appears that canoeing, boat camping, and auto camping have all been increasing rapidly since the air ban in 1949-52. This is the general opinion of local Forest Service personnel and tourist businessmen. It also corresponds to conclusions based on changes in the numbers of canoe outfitters compared to resorts. Most of the outfitters have prospered and grown and have fleets of canoes stacked like cordwood. As another indication, accurate counts kept by the operator of the railroad portage into Lac La Croix since 1957 show that canoes increased 83 percent in 4 years.

The rapid growth of young people's camps means still more canoeing. The largest camp is the Region 10 Boy Scout Canoe Base on Moose Lake. In 1948 less than 500 Scouts used the base; in 1961 2,340 poured through—almost five times as many. The other camps have also grown substantially. About half of the present youth camps started after 1948. In addition many camps elsewhere in Minnesota and Wisconsin now send some groups to the area for canoe trips.

The earliest known estimate of numbers of canoeists refers to 1940—2,000 people (Chapman 1945, p. 98). In 21 years the number grew to about 35,000 canoe trippers (during the entire year), with over 6,000 others canoeing without taking a trip.

In 1948 the Forest Service, in connection with the air ban, estimated users as follows:[14]

15,660	by canoe
11,000	by seaplane
21,610	by motorboat
48,270	— Total

From this it is also clear that canoeing has increased more than boating—nearly three times—while boating has about doubled.

There is no such index of boat camping because boat campers are self-contained and bypass resorts and the like. General observation at access points suggests a rapid increase. The operator of the Lac La Croix railroad portage started counting boat campers in 1958. They increased 64 percent in the next 3 years. It is also indicative that boat trailer sales in 1956 were 40 times greater than in 1947 (Clawson 1958, p. 61).

On the other hand, no new resorts have been built within the study area since 1950; and since 1946, 33 inside the Boundary Waters Canoe Area have been purchased and removed by the Forest Service. The remaining resorts have expanded about 15 to 25 percent, according to local estimates, but probably not enough to offset the decrease in capacity. The resort business appears only fair—two resorts were closed during 1960, and one was bought by a young people's camp and converted. Business may still be better, however, than in comparable areas in Minnesota because of the wilderness attraction.

Again, the Lac La Croix railroad portage data are useful: From 1959 to 1961 resort traffic increased only 3 percent.

Private cabins have increased perhaps 25 to 50 percent since 1950, despite the purchase and removal of 73 cabins inside the Boundary Waters Canoe Area by the Forest Service.

Auto campground use has also grown, probably faster than capacity has been added. This is the only category for which trends (but not totals) can be extracted from the official estimates. From 1946 to 1960 there was about a 480-percent increase or about 14 percent a year. This is higher than the 12-percent rate of total Boundary Waters Canoe Area visits, but may be slightly lower than for canoeing and boat camping.

Some of the estimates based on the preliminary field work in 1960 can be compared very cautiously with the 1961 data—cautiously because the 1960 data were not fully satisfactory and because an adjustment for different survey periods is necessary. The figures on canoe use and boat camping are most reliable. Estimated canoe use increased 40 percent,[15] and boat camping 46 percent. In contrast, business records indicate resort use increased only 4 percent from 1960 to 1961.

In summary, the past decade has shown very rapid growth in canoeing and boat camping, rapid increase in auto camping, moderate growth in private cabin

[14] *From the files of the Superior National Forest, Duluth, Minn., as Exhibit "D" sent to I. H. Polk, Secretary, Air Space Subcommittee of the Air Coordinating Committee, Civil Aeronautics Administration, March 23, 1949.*

[15] *This figure corresponds exactly to an estimate made by the Ely Chamber of Commerce and reported in the Minneapolis Tribune, Oct. 21, 1961.*

use, and slow expansion of resort use. The dispersed uses, which require little or no construction of facilities, grew fastest, while the uses requiring substantial capital investment lagged. Auto campgrounds, which require an intermediate amount of building, grew at an intermediate rate. This relation to supply elasticity is to be expected in the short run, but 10 years is a rather long short run. The resort response apparently reflects market problems more than a time lag in construction.

These fragmentary records are not sufficient for mathematical projections of types of use. There is no reason, however, to expect the recent relative growth rates to change greatly. The management policies appear to be stable into the foreseeable future. The elimination of the remaining internal resorts and cabins will probably be complete soon, but the present use of these facilities is not large. New access roads around Quetico Park should accentuate the growth of canoeing and especially boat camping, as seems to have happened at French Lake. Facilities probably will continue to grow adequately for these projected demands. The Forest Service is increasing campground capacity substantially under the Public Works Acceleration Program, and there is the possibility of a further step-up of campground construction if the 10-year program proposed by the Forest Service is carried out. This program provides for over a sixfold increase in National Forest campground numbers and capacity. Whether this would saturate demand and reduce crowding or stimulate a surge of visits is not known.

Looking further into the future is still more difficult, but some of the characteristics of the various sorts of users lead to some interesting speculation when related to the ways society seems to be changing. Table 12 presents a socio-economic description of the visitors.

Occupation trends for males have been computed for the period from 1950 to 1959. Changes in the number of individuals in each class were:

Occupational Class	*Percent Change*[1]
Professional, Technical	+ 52
Farmers, Farm Managers	— 28
Proprietor, Manager, Official	+ 34
Clerical, Sales	+ 9
Skilled Labor, Foreman	+ 9
Other Labor	+ 5
Retired[2]	+ 40

[1]Sources of data are: Tables 278 and 347, Statistical Abstract, 1959; table 287, Statistical Abstract, 1954. Same approximation for retired persons as was used in table 12 (footnote 3, Category II).

[2]Data years for retired persons are 1951 and 1958; hence the difference in percent is for 7 years instead of 9.

A continuation of these trends, assuming that the rates of participation in different sorts of recreation for each occupational category do not change, would lead to paddling canoeists increasing most rapidly. About three-fourths of the paddlers (excluding students) were professional-technical people, the most dynamic occupational category. If the 1950-1959 percent change for each occupation category is multiplied by the percent of the recreation class belonging to that occupation, and the values for each type of recreation are totaled, the results are:

Paddling canoeists	142
Motor canoeists	129
Resort guests	129
Auto campers	124
Private cabins	123
Boat campers	113
Day users	110

These are only index figures showing the relative impact of recent occupation trends. They are not projections of percent change for any target year.

Changes in the number of families and unattached individuals in various income classes, 1950 to 1958, were:

Income Class	*Percent Change*[1]	
$ 0– 1,999	— 30	
2,000– 3,999	— 27	
4,000– 5,999	+ 8	
5,000– 7,499	+ 94	+ 119
7,500– 9,999	+ 153	
10,000–14,999	+ 216	
15,000–24,999	+ 198	
25,000–49,999	+ 100	
50,000 and over	+ 68	

[1]Sources of data: Statistical Abstract, 1959, table 409, and Survey of Current Business, July 1961, table 18.

These are incomes for families and are, therefore, higher than the head-of-household figures in Table 12 for any families with more than one member receiving income. The following indices of relative growth are obtained from the projected changes for each income class. (The same method and limitations mentioned in connection with occupation indices apply here.) The very well-to-do resort guests head the list:

Resort guests	160
Private cabins	144
Paddling canoeists	139
Motor canoeists	137
Auto campers	131
Boat campers	117
Day use	95

The Census Bureau has projected educational attainments to 1980:

TABLE 12. — *Selected social characteristics of visitors[1] to the study area 1960-61*

Category	Canoeists		Campers		Resort guests	Private cabin	Day use[2]	National[3]
	Motor	Paddle	Auto	Boat				
I. INDIVIDUALS								
Number	87	350	424	83	218	92	47	-
Males (Percent)	87	82	54	69	60	62	60	49
Females (Percent)	13	18	46	31	40	38	40	51
Age (Percent of total):								
1-12 years	3	5	29	12	17	17	27	27
13-19 "	40	59	16	11	6	21	11	11
20-34 "	36	20	14	20	13	22	26	19
35-54 "	12	14	37	46	42	17	27	25
55 and over	9	2	4	11	22	23	9	18
II. OCCUPATION (CENSUS BUREAU DEFINITIONS) PERCENT OF TOTAL MALES OVER 17 NOT IN SCHOOL								
Professional, technical	26	71	26	15	27	27	6	9
Farmer, farm manager	5	1	4	2	3	4	0	6
Proprietor, manager, official	32	13	17	2	30	4	0	12
Clerk, sales	0	7	7	11	9	12	6	12
Skilled labor, foreman	13	2	21	39	13	23	31	17
Other labor ("operatives," service workers, laborers)	19	6	22	22	9	18	57	34
Retired	5	0	3	9	9	12	0	10
III. STUDENTS--AS A PERCENT OF TOTAL								
Percent	46	69	40	20	19	34	23	25
IV. ANNUAL INCOME OF HEAD OF HOUSEHOLD (BEFORE TAXES)--PERCENT OF TOTAL[4]								
$ 0 - 1,999	0	0	0	2	1	0	0	15
2,000 - 3,999	12	12	8	2	4	12	6	22
4,000 - 5,999	30	21	34	55	15	16	44	23
6,000 - 7,999	19	28	33	22	20	32	38)	27
8,000 - 9,999	11	9	9	10	8	6	6)	
10,000 - 14,999	19	16	12	7	30	17	0	9
15,000 - 24,999	3	9	4	2	13	11	6	3
25,000 - 49,999	6	5	0	0	8	6	0	1
50,000 and over	0	0	0	0	1	0	0	0.3
V. EDUCATIONAL LEVEL OF THOSE WHO HAD COMPLETED SCHOOL--PERCENT OF TOTAL								
0 - 8 years	13	0	12	9	10	11	20	50
9 - 11 "	13	4	10	28	8	17	7	15
12 - "	23	17	43	38	37	23	63	22
13 - 15 "	15	12	15	9	13	17	10	8
16 - "	25	42	14	13	24	19	0)	5
17 and over	11	25	6	3	8	13	0)	

1/ Visitor data from long interviews.

2/ Day use does not include auto sightseers.

3/ The national figures presented here were obtained from the following sources:

Category I. (no. of individuals): U. S. Census of Population: 1960, General Population Characteristics, United States Summary. Table 46, pp. 148-149.

Category II. (occupation): From Statistical Abstract of the United States, 1959. Table No. 278, Major Occupation Group and Class of Worker of Employed Persons, Males, 1959; and table No. 347, Selected Characteristics of the Civilian Population 65 Years Old and Over, Males Not in Labor Force, 1958 (as an approximation of retired males). The figures given are the percent of the total of these two groups.

Category III. (students): Statistical Abstract, 1959, tables 2 and 128. Figures refer to 1958.

Category IV. (annual income): Consumer units and family personal income, before income taxes, 1958, from Survey of Current Business, July 1961, table 18. These figures are not the same as head of household income, due to supplementary income from wives, etc. Although the general shape of the distribution is similar, it is moved upward relative to study data.

Category V. (educational level): From Statistical Abstract, 1959, table No. 141. Data for West North Central area only; years of school completed by persons 25 years old and over, 1950, for Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, and Kansas.

4/ Groups consisting entirely of students are excluded.

Years of School Completed	*Percent Change*[1] *1960-80*
0– 8	— 31
9–11	+ 40
12	+ 90
13–15	+ 69
16 or more	+ 91

[1]Source of data: Statistical Abstract, 1959, table 142, Series A (short-term) trends.

If recreational visits within each educational category were to change at these rates, the changes in national educational levels would produce the greatest increase among paddling canoeists, who usually were very well educated. The index numbers, using the same multiplying procedure previously described, would be:

Paddling canoeists	188
Resort guests	171
Motor canoeists	167
Auto campers	167
Private cabins	165
Boat campers	163
Day use	161

Whether there is a causal connection between these social characteristics and the choice of recreation has not been proved, but it seems reasonable that education and occupation, which are strongly related, would have a great deal to do with shaping tastes.

Income, also related to education and occupation, is probably less a causal factor and more a reflection of the type of work and the amount of schooling. This conclusion seems to follow from the fact that price differences between the various classes of Quetico-Superior recreation are rather small. Complete canoe outfitting costs about $6 per person per day compared to daily rates of $10 to $12 per person at American plan resorts. Camping involves less direct outlay after the basic equipment has been acquired. Two weeks' camping each year might cost only $15 per week (plus the cost of food) if the life of the equipment is assumed to average 10 years. This could be compared to $40 to $60 per week for a housekeeping cabin. Boat camping is more expensive, because of the additional boat expense. All of these classes—even resort guests—enjoy many free recreation goods and services because of the public provision of lakes, scenery, fish, portage trails, and the like, thereby reducing the role of price in choosing recreation. Also, although income probably changes more for individuals over time than does education level or major occupational class, data previously presented indicated that individual recreational preferences are quite persistent. Income seems to be more *necessary* than *sufficient* as an explanation of recreation choices. Money does not form tastes, it limits their expression, but few people would be priced out of the market here for any type of recreation, with the possible exception of the American plan resorts and private cabins.

Population trends also suggest only small differences in the relative rates of increase for each type of recreation. Population change, 1959 to 1976, has been projected as follows:

Area	*Percent Change*[1]
Minnesota	27
Dakota	20
Iowa	17
Illinois	22
Wisconsin	25
Michigan, Ohio, Indiana	35
Missouri, Kansas, Nebraska	24
Northeast[2]	28
South[2]	27
West[2]	45
Total U. S.	30

[1]Source of data: National Forest Recreation Survey, supplementary data contained in memorandum from Washington Office dated Aug. 5, 1960, in files of the Lake States Forest Experiment Station, St. Paul, Minn.

[2]Defined in notes on table 6, p. 20.

Regions within Minnesota were treated individually because Minnesota accounts for a large proportion of all visitors, but population growth rates vary greatly within Minnesota. The resulting index numbers for the increase in total visits due to population growth are:

Resort guests	131
Private cabins	131
Paddling canoeists	129
Auto campers	128
Motor canoeists	127
Boat campers	125
Day use	121

The construction of the Interstate Highway System, which will reach Duluth, would be expected to contribute most to the relative accessibility of more distant areas; these are the most important as source areas for paddling canoeists and resort guests, and least important for day users and campers. The meaning of travel time to location choices, however, is not well understood. Travel time may be effective in zones, rather than continuously, and improved highways might bring the Canoe Country into the weekend camping zone.

Summary of Projections by Types of Use

The trends suggested by these four factors—occupation, income, education, and residence—agree quite

well. Day use was the least dynamic in every case. That boat camping was next lowest on all four is interesting because this type of visitor seems to have increased very rapidly in the past. The implications are that technology (light metal boats, improved motors, and better boat trailers) opened new possibilities which were quickly exploited, but that the sorts of people with preferences for boat camping in this area are not a rapidly expanding portion of the population and consequently this activity may level off. Sales of boats, outboard motors, and boat trailers all reached peaks between 1956 and 1960 and have dropped substantially since then (Nat. Assoc. of Engine and Boat Mfrs. and Outboard Indus. Assoc. 1962).

The canoeists who paddle seem to be the most dynamic social group; they lead in growth rates on the basis of occupational and educational changes, and they are third on the basis of population shifts in areas of residence (the factor for which differences were smallest). Only for income shifts do canoeists move very far down in the rank order of growth indices — below resort guests and users of private cabins—but income is probably a less critical variable.

The resort category also seems to have great expansion possibilities; it is first or second on every measure. Private cabin use, auto camping, and motor canoeing seem intermediate, with cabin use perhaps a little higher.

All of these conclusions rest upon three assumptions: First, that for any given class of people, preferences and their expression will retain the same relationship to the four variables over time; second, that these are the major variables; and third, that for the first three measures, national trends represent the visitor source areas. Certainly none of the assumptions is completely met, but they may be near enough to the truth to produce useful expectations. A literature search indicates that no studies of the formation or change of outdoor recreation tastes have been made, so there is no basis for refining the first two assumptions.

Use by Areas

The survey data cannot provide a base for estimating trends in the distribution of use; but some very general conclusions could be drawn from the past trends for types of use. Reasoning this way, one would suspect that Moose Lake and Crane Lake have increased at an above-average rate because canoeing, in which Moose Lake leads, and boat camping, concentrated at Crane Lake, have been particularly fast growing. The difference between fringe use and interior use may also have decreased because the uses with more gradual gradients (canoeing) seem to have been growing faster than the predominantly marginal uses (boating). These general areal trends probably will continue into the future.

Data for visitors entering Quetico Park at each of its official access points (Table 13—see Plate I for locations) show that Lac La Croix, where most of the visitors are motorboaters, had the most rapid increase between 1958 and 1961. But the figures are of doubtful comparability. In 1961 an American resort and seaplane operator at Crane Lake was authorized to issue Quetico Park travel permits for the Lac La Croix area to his customers. These people accounted for most of the increase, and it is likely that some of them previously entered the part of the lake in Quetico Park unofficially. Beaverhouse Lake also had a rapid increase from a small base. This point, primarily used by Crane Lake seaplanes, was unlike any other entry point. French Lake expanded very rapidly after the road was opened in 1957. The largest increase in number of visitors was at Basswood Lake, which had two entry points, but the rate was lower. Over half of all entries were made on Basswood. Saganaga Lake was the only entry point where a large comparable lake area existed in Canada outside the Park, which may have led to some people choosing not to enter the Park, and contributed to the low increase. Some outfitters in the Saganaga area also kept a number of canoes without the $5 stickers and recommended trips outside Quetico.

These 3-year Quetico trends, if continued, would have the effect of spreading use more evenly, but the basis for establishing the trends is very short.

TABLE 13. — *Quetico Park visitors by access points, 1958, 1960, and 1961, and percent of change*[1]

Access point	1958	1960	1961	Change 1958-61
	Number	Number	Number	Percent
Lac La Croix	1,435	2,082	3,277	128
Beaverhouse Lake	514	813	1,018	98
French Lake	2,894	3,737	5,632	95
Basswood Lake[2/]	9,895	9,030	13,244	34
Saganaga Lake	1,571	1,276	2,019	29
Total	16,309	16,938	25,190	54

1/ Data are from official records. Figures for 1959 and years before 1958 were unavailable.

2/ An international Scout meeting in Colorado in 1960 resulted in fewer visitors to the Boy Scouts canoe base and largely accounts for the smaller Basswood Lake figure for that year.

SUMMARY AND CONCLUSION

The Quetico-Superior Area is a large region, partly preserved and partly restored to provide a primitive setting for recreation, especially canoeing, with logging limited but not prohibited. It is a semi-wilderness. This is a type of area which was called for by Robert Marshall, the founder of the Wilderness Society and one of the people most responsible for the National Forest Wilderness Areas (Marshall, 1933, pp. 473-476). This call for semi-wilderness as part of a full range of types was repeated by the Outdoor Recreation Resources Review Commission (1962a, p. 71) and by A. H. Carhart (1961). The Boundary Waters Canoe Area is the only official semi-wilderness area in the United States and, therefore, it is of particular interest.

The location and physical geography of the area led to late and limited settlement and economic development of the Quetico-Superior, and made possible the public policy of maintenance and restoration of primitive waterways. The same two factors have led to use predominantly by Midwesterners, for whom it is the closest wild land and almost the only canoe country.

Amount of use. — Use was substantial. About 132,000 people visited the study area during the main summer season of 1961, and over 72,000 used the Boundary Waters Canoe Area. Apparently the study area may account for half of the overnight recreational use of the three northeastern Minnesota counties of St. Louis, Lake, and Cook, despite the large area in the three counties outside the study area and the competing attraction of the Lake Superior North Shore highway. The Boundary Waters Canoe Area alone may account for one third of all overnight man-days in the tri-county area. Both of these conclusions are based upon estimates of visitors other than campers for 1958 (Sielaff, 1959) plus an estimate of State Park and National Forest campers.

Types of use. — Canoe tripping was the largest of the seven types of use (32,000 people), but for the entire study area more people boated than canoed (five of the other user types were mainly boaters). Even within the Boundary Waters Canoe Area there were almost as many boaters as canoeists. Auto sightseers were second, followed by resort guests, auto campers, boat campers, one-day visitors, and private cabin users.

Distribution of use. — Maps of every type of use tell the same story; a few places had most of the visitors, and most places had very few. One tenth of the access points had over half of every type of use. This very uneven distribution does not seem optimal if solitude is a goal. Furthermore, the canoeists, who most desired solitude,[16] were the most concentrated in terms of access point use. Over half of the paddling canoeists used the Moose Lake access.

The patterns of concentration differed from type to type. Considering access point use first, canoeists formed one class, auto campers a second, day users a third, and all other boaters a fourth. For all types except day use, large border lakes were much more heavily used than southern areas, and for canoeists especially, places close to Quetico Park had the heaviest use.

Away from access points, boating and canoeing differed sharply. Only about one fifth of the boaters went over unmechanized portages, but many used mechanized portages; as a result two large lobes extended along the border from an otherwise marginal use distribution. Boaters were vague as to reasons for choosing their route. Canoeists went much farther, especially paddlers, and almost all of the area was visited—much of it by only a few parties, however. Canoeists were more definite concerning the basis for their choice of route, but outfitters' advice was the leading reason. The Canadian border did not act as a significant barrier for either boaters or canoeists.

Trends in use. — Total use of the Boundary Waters Canoe Area has been increasing at about the same 12-percent rate as all National Forest recreation visits. Use of Quetico Park has been increasing slightly faster. Canoeing seems likely to increase the most in the future.

The Prospect. — The large, lightly used areas are mainly in the southern Boundary Waters Canoe Area, and to a lesser extent in western Quetico Park. These areas seem attractive. Are they a potential for the expected increase in future use? The answer to this question depends upon the identification of the carrying capacity of a wilderness-type recreational area. This is a difficult problem, but a tentative system has been developed and it will be presented in a subsequent paper which will build upon this one.

[16] *Data on this point will be contained in a later paper.*

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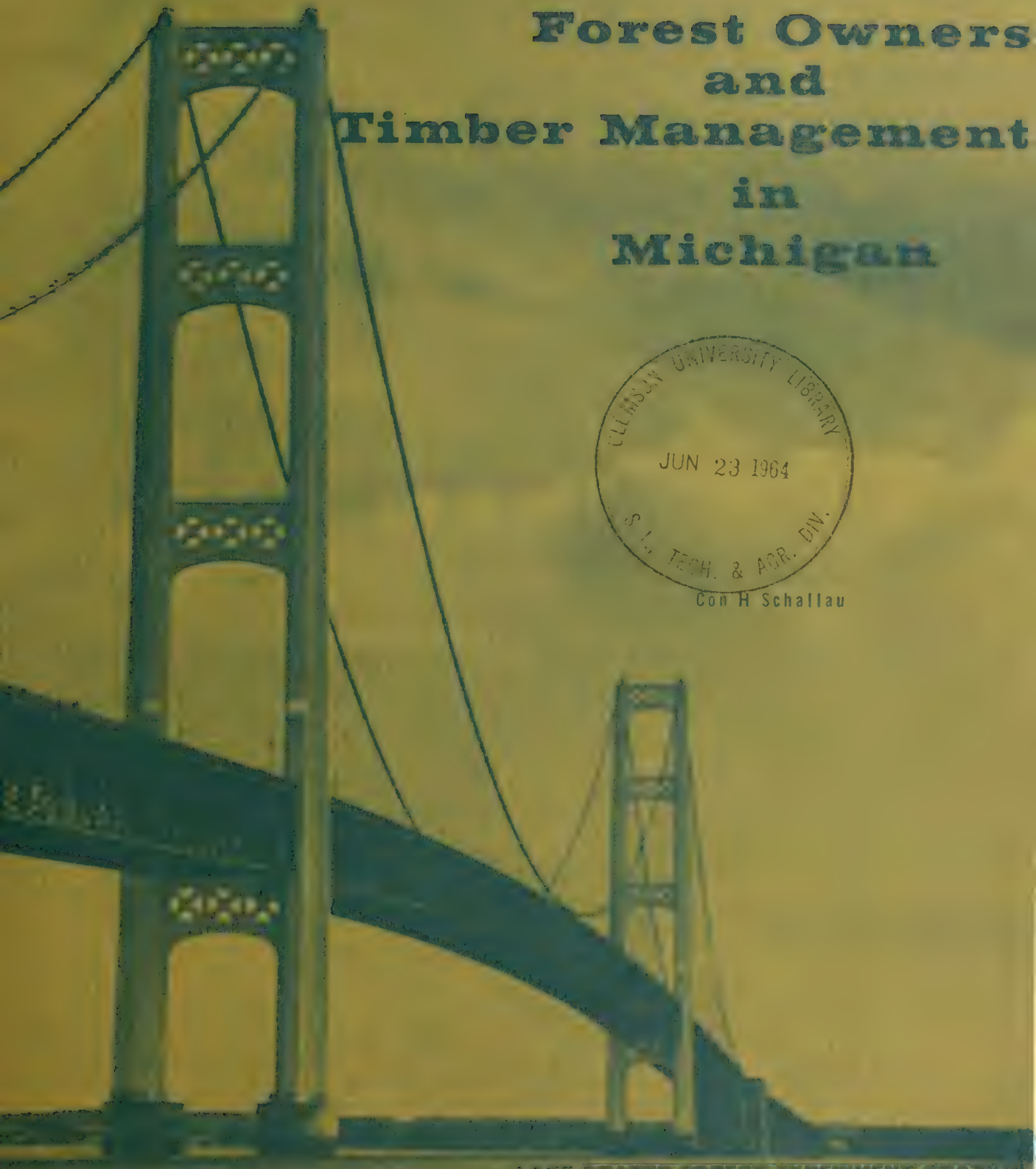
Forest Owners and Timber Management in Michigan



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LAKE STATES FOREST EXPERIMENT STATION
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FOREWORD

The responsibility for managing the 51.6 million acres of commercial forest land in the Lake States region is divided among three major ownership classes: (1) public, (2) "large private," that is, individuals and corporations having more than 5,000 acres, and (3) private individuals and corporations owning less than 5,000 acres. Ownership research at the Lake States Station has dealt mainly with the latter group — the "small ownerships." This report is unique in that it discusses public and large private ownerships as well as the small ownerships.

The author is indebted to numerous individuals for their help in preparing this paper. He is especially grateful for the assistance of the staffs of the Forestry Division of the Michigan Department of Conservation, Lansing, Mich., and the U.S. Forest Service's North Central Region office, Milwaukee, Wis. Drs. Dean N. Quinney, Lake States Forest Experiment Station, and James G. Yoho, School of Forestry, Duke University, are thanked for granting permission to abstract liberally from unpublished results but are not implicated by the author's use.

Majestic Mackinac Bridge linking the wooded shorelines of Michigan's two Peninsulas. Providing a convenient vacation route to the North Country, this bridge should stimulate increased use of Michigan's forest recreational facilities. (Photo courtesy of Michigan's Tourist Council.)

CONTENTS

Page

INTRODUCTION 1

SOURCE OF DATA 3

THE STUDY AREA 3

SMALL PRIVATE FOREST LANDOWNERS 5

- General Characteristics 5
- Timber Products Marketing Activity 9
- Woodland Improvement and Tree Planting Efforts 12
- Owner's Recognition of the Need for Improved Forest Management 12
- Interest and Participation in Forestry Assistance Programs 14

LARGE PRIVATE FOREST LANDOWNERSHIPS 19

PUBLIC FORESTS 21

- State Forests 21
- National Forests 27

DISCUSSION AND CONCLUSIONS 32

LITERATURE CITED 39

Four abstract cards are included at the back of this report for the reader's convenience.

FIGURE 1. — Abitibi Corporation's new modern pulpmill at Alpena. Although lumber was once the major product from Michigan's forests, it was surpassed by pulpwood products during the 1950's. (Photo courtesy of Hunting Survey Corporation Limited, Toronto, Canada.)

INTRODUCTION

Use of Michigan's forests began shortly after the pioneers started to move westward beyond the Appalachians. Settlement of Michigan began in earnest after the opening of the Erie Canal in 1825. The first settlers were interested in farming, and since the State was almost entirely forested they faced a formidable land-clearing job. Small sawmills sprang up all over southern Michigan to supply lumber for building, but despite this use the forests were considered a hindrance. Much of the original forest cover in southern Michigan was windrowed and burned to make way for agricultural production.

The original forests in Michigan contained roughly 380 billion board feet of sawtimber (Sparhawk 1929, p. 6).[1] This is more than 15 times the present sawtimber volume. Although there was some early hardwood logging in southern Michigan, it was the pine forest of the Saginaw Valley, the Thumb area, and, a little later on, areas farther north that made Michigan famous as a midwestern lumber producer. Increased demand from eastern markets and the settlement of the Prairie States provided the impetus for the rapid growth of the pine lumber industry in Michigan after 1850.

Early loggers harvested timber as if the supply were unlimited. Subsequently they were proven wrong because, as the tabulation below shows, the expansion of Michigan's lumber industry was relatively short-lived.

Year	*Billion bd. ft. of lumber produced*
1870	2.4
1880	4.3
1890	5.2
1900	2.8
1910	1.8
1920	.8
1930	.5
1940	.4
1950	.5
1960	.3

Source: Bureau of the Census records

The peak year for lumber production was 1889 when 5.4 billion board feet were produced. Michigan led the Nation in lumber production for 30 years, but by the turn of the century lumber barons were starting to move to the South and West where sawtimber supplies were more abundant (fig. 1). Michigan's original supply of pine had nearly been exhausted. By 1925 it ranked 25th in the Nation in lumber production.

Although most of the original timber volume was harvested for lumber and other wood products, much went up in smoke. Sparhawk (1929, p. 9) has estimated that 35 billion board feet were cut and burned in clearing land for farms. An additional 73 billion feet were burned during or after lumbering, or were destroyed by forest fires independent of cutting operations. The removal of forest cover was considered beneficial at the time since farming was expected to thrive in the cutover areas of Michigan.

Actually the farmers did fairly well as long as the lumber industry prospered, but with its decline the farms encountered hard times. Realization that much of Michigan's cutover area was unsuitable for agriculture led to the collapse of the land boom in the 1920's. Widespread tax forfeiture of cutover and burned-over forest land followed. Subsequent increases in property taxes and the economic depression of the 1930's caused more land to be forfeited. Although Michigan's State and National Forest systems date back to the early 1900's, much of their growth can be attributed to the abandonment of these "unwanted" lands.

In 1920 nearly all of Michigan's forest resources were in private hands, but since then the situation has changed. A third of the commercial forest land in the State is now publicly owned (table 1).

But during the decades since 1920 Michigan's forest resources have undergone other changes besides those in ownership patterns. Pine lumbering was nearly finished, but logging continued to

[1] *Names and dates in parentheses refer to Literature Cited at the end of this report.*

Note: The author is a Forest Economist at the Lake States Forest Experiment Station. The Station is maintained at St. Paul, Minnesota by the Forest Service, U.S. Department of Agriculture, in cooperation with the University of Minnesota.

TABLE 1. — *Commercial forest land, by ownership and region, Michigan, 1955 (after Findell et al. 1960)*

(In thousands of acres)

Owner	Upper Peninsula	Lower Peninsula		State
		North half	South half	
Federal	1,709	805	16	2,530
State	1,796	1,780	119	3,695
County and municipal	54	20	11	85
Private	5,480	4,903	2,428	12,811
All owners	9,039	7,508	2,574	19,121

reduce timber volumes for several decades. Cutting of the slow-growing, mature hardwood and hemlock forests in the Upper Peninsula accounted for much of this reduction. The total growing stock volume probably reached an all-time low during the mid-1940's and has now climbed to a pre-1935 level as shown below:

Year	*Growing stock volume (billion cu. ft.)*	*Sawtimber volume (billion bd. ft.)*
1935	10.4	26.3
1945	8.2	19.0
1955	10.7	23.8

Source: Forest Survey statistics

The "thickening up" of the forests can be attributed to hardwood cordwood growth since softwood growing stock and sawtimber volume had dropped 27 percent and 34 percent respectively since 1935. Sawtimber volume of all species was greater in 1955 than in 1945 but was still less than in 1935.

Present stocking of Michigan forest land is only a fraction of what it once supported. Just as an example, Gevorkiantz and Duerr (1937) estimated that typical old-growth northern hardwood stands in the Upper Peninsula ran from 2,000 to 3,000 cubic feet of growing stock per acre at 100 years. Average stocking of second-growth northern hardwood stands in 1955 was approximately 500 cubic feet per acre. Although it may not be economically desirable to again maintain growing stock at such high levels (the original stands were overmature and growth was negligible), the comparison indicates that the level of stocking could be increased considerably. Whether it actually will be increased is partially dependent upon the efforts of forest-land owners to institute better management practices in the near future.

This report describes the levels of timber management being carried out by Michigan's private and public forest-land owners and speculates on the implications of such efforts in terms of future timber supplies. More specifically this report —

1. Shows who the various types of forest-land owners are, how much forest land they own, and how they manage their forest land and market their timber products.
2. Describes factors that inhibit the adoption of more productive management practices by certain classes of owners.
3. Assesses the effectiveness of various public assistance programs in promoting certain forestry practices among woodland owners.
4. Evaluates the trend of timber products output from Michigan's forest land in the light of the types of management practices (or lack of them) adopted by the various classes of owners.

The results of the study are divided into three major sections: (1) the small private forest-land ownerships; (2) the large private forest-land ownerships; and (3) the public forests. Emphasis is on the small ownerships, but the large ownerships and public forests are included to place the others in better perspective.

SOURCE OF DATA

The section on small private owners summarizes three small forest-land ownership studies conducted during the 5-year period 1954-59. Two of these studies (one for the Upper Peninsula and the other for the southern half of the Lower Peninsula) were made by the Lake States Forest Experiment Station (Quinney 1962, Schallau 1962). The Station cooperated with Michigan State University in making the third study which encompassed the northern half of the Lower Peninsula (Yoho et al. 1957, Yoho and James 1958).

The three small woodland ownership studies involved sampling from a very large population of individuals. Approximately 182,000 forest-land owners in Michigan have from 3 acres to 5,000 acres of forest land; of these, 634 were interviewed (198 in the Upper Peninsula and 229 in the northern half and 207 in the southern half of the Lower Peninsula). Details of the sampling schemes used in these studies can be obtained from the individual reports. It should be pointed out here that in the study of the northern half of the Lower Peninsula a slightly different population was sampled; *all* private owners were considered. The other two studies considered only those private owners with 5,000 acres or less of forest land. This does introduce some bias, but because the sampling rate was very low and the total number of large owners in the northern half of the Lower Peninsula is relatively small, the bias was judged to be unimportant.

Information used in the discussion of management of large private ownerships was obtained from public officials and published announcements rather than from the individual owners. The section on Michigan's public forest lands is based on data obtained from the Michigan Department of Conservation and from the U.S. Forest Service North Central Region office in Milwaukee, Wisconsin.

THE STUDY AREA

The State of Michigan can conveniently be divided into three geographical areas (fig. 2): (1) the Upper Peninsula, which is separated from the remainder of the State by the Straits of Mackinac, (2) the northern half of the Lower Peninsula, and (3) the southern half. These are the major subdivisions used in the Forest Survey of the State.

Michigan's population is concentrated in the southern half of the Lower Peninsula. Here 91 percent of the State's 7.8 million people reside. The remainder of the population is almost equally distributed between the other two subregions — 4 percent in the Upper Peninsula and 5 percent in the northern half of the Lower Peninsula. During the period between the 1950 and 1960 Censuses, Michigan's population increased by 22.3 percent or by nearly 1½ million people, mostly in southern Michigan. North of a line between Muskegon and Bay City, population increased by only 5.3 percent. In the area south of this line, the population rose

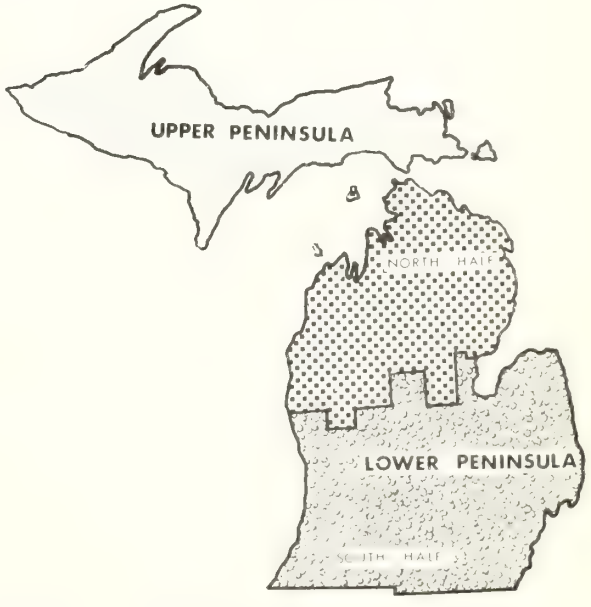

FIGURE 2. — Three geographical areas of Michigan.

by more than 24 percent. Outward migration and a lower birth rate are the reasons for the slower population growth in the northern counties.

Until the last decade the population of the Upper Peninsula was gradually decreasing after reaching an all-time peak in 1920. Actually, 3 of the Upper Peninsula's 15 counties accounted for most of the growth between 1950 and 1960, largely because of the enlargement of two military installations. Eight counties continued to show decreases in population.

The major part of Michigan's economy is located in the southern half of the Lower Peninsula. For instance, in terms of value added by manufacturing, that area accounted for 95 percent of the dollar value in 1958 while the Upper Peninsula and northern half of the Lower Peninsula supported only 1 percent and 4 percent respectively. The northern counties have a somewhat larger share of the number of farms than they do of the value added by manufacturing — 6 percent for the Upper Peninsula and 19 percent in the northern half of the Lower Peninsula. However, in terms of the value of agricultural products produced, the relationship is more like the value-added figures: 3 percent of the total in the Upper Peninsula, 12 percent in the northern half, and 85 percent in the southern half of the Lower Peninsula.

Unlike most other sectors of the State's economy, timber production is concentrated in the more northern counties, a reflection of the distribution of forest land. More than half of the State's forest area is located in the Upper Peninsula (table 2), which is 89 percent forested compared with only 17 percent in the southern half of the Lower Peninsula.

TABLE 2. — *Land areas, by major classes of land and Forest Survey district, Michigan, 1955*
(In acres)

Class of land	Upper Peninsula	Lower Peninsula		State
		North half	South half	
Forest	9,409	7,651	2,639	19,699
Nonforest:				
Farm	634	2,463	10,332	13,429
Other	542	622	2,202	3,366
Total	10,585	10,736	15,173	36,494

As the tabulation below shows, the Upper Peninsula far surpasses the other two sections of the State in terms of the total value of rough forest products harvested (1954 data).

	Percent of total value
Upper Peninsula	61
North half of Lower Peninsula	20
South half of Lower Peninsula	19

Considering that the southern half of the Lower Peninsula is so heavily industrialized and populated and that much of the land area is in agricultural production, it makes a notable contribution to the State's forest economy. Although this area is only 17-percent forested it supplies nearly as much of Michigan's rough forest products, in terms of dollar value, as does the northern half of the Lower Peninsula, which is 71-percent forested. The reason lies in the type of timber product produced; in the northern half of the Lower Peninsula the major product is pulpwood, while higher per-unit-value hardwood sawtimber accounts for most of the cut from southern Michigan's forests. Furthermore, the southern half of the Lower Peninsula shows more potential for timber production on a per-acre basis. Annual net growth in cords per acre on commercial forest land was: 0.29 cord in western Upper Peninsula; 0.34 in eastern Upper Peninsula; 0.30 in northern Lower Peninsula, and 0.40 cord in southern Lower Peninsula.

Ownership of forest land in the Upper Peninsula and the northern half of the Lower Peninsula is quite similar (table 3). Public agencies own slightly more than a third of the forest land in both of these areas. Private ownership, on the other hand, accounts for all but 5 percent of the forest land in southern Michigan. Large private ownerships (over 5,000 acres in size) are quite prevalent in the Upper Peninsula, accounting for about one-half of the privately owned forest land. They account for only 4 percent of the total forest area in the northern half of the Lower Peninsula and practically none in the southern half.

Michigan's forests are thickening up, but the magnitude of the increases varies by ownership classes. For instance, growing stock volume on public forest land increased 55 percent between 1945 to 1955 — from 1.9 billion to 2.9 billion cubic

TABLE 3. — *Distribution of commercial forest area, by ownership and Forest Survey district, Michigan, 1955*

(In percent)

Ownership class	Upper Peninsula	Lower Peninsula		State
		North half	South half	
Public:				
Federal	19	11	*	13
State	20	24	5	19
Other public	*	*	*	*
Private:				
Large (over 5,000 acres)	29	4	*	15
Small (less than 5,000 acres)	32	61	95	53

* *Less than 0.5 percent.*

feet. Volume on private lands increased only 23 percent during the same period — from 6.3 to 7.8 billion cubic feet. Sawtimber volume on public lands increased from 1.8 to 5.6 billion board feet, or 211 percent between 1945 and 1955, while on private lands it rose 64 percent — from 17.1 to 18.2 billion board feet.

In addition to a faster increase in growing stock, public forest lands are supporting an ever-larger proportion of the total timber cut from Michigan's forests. In fact, while the total cut for the State dropped from 216 million cubic feet in 1950 to 178 million in 1960, the cut from both State and Federal lands was on the upswing. For instance, cut of growing stock from State forests was 4.6 million cubic feet in 1951 and 19.7 million in 1960. The cut from National Forests in Michigan was 6.0 million cubic feet in 1951 and 21.7 million in 1960. In 1950 public lands accounted for 7 percent of the State's cut from growing stock, while in 1960 the public land share had increased to 23 percent.

Several changes in land use trends during the post-war period will influence the State's future output of timber products (fig. 3). For one thing, the acreage of farmland is on the decline; according to the 1959 Census of Agriculture it dropped 14 percent during the 1949-59 period.[2] Some of this idle farmland may eventually revert to forest cover, especially in the northern sections of the State, but more importantly existence of idle farmland may reduce the tendency to clear forest land for agricultural purposes.

Another change in agricultural land use that will probably have a direct and immediate effect on timber production is the decline in the acreage of grazed woodlots. This decline, amounting to 47 percent between the 1949 and 1959 Censuses of Agriculture, should lead to an increase in quality as well as in quantity of timber being produced in Michigan.

In southern Michigan still another change in land use is occurring. This is the urban growth around the large metropolitan areas. Urbanization influences timber production by reducing the acreage of forest land. Indirectly it can reduce the economic supply of timber by isolating pockets of growing stock from timber marketing channels.

[2] *At the time of the last Census of Agriculture, over 200,000 acres of farmland had been retired under the Soil Bank Program. About 94 percent of this acreage involved whole farms and was not included in the 1959 enumeration. So participation in the Soil Bank Program led to about a 4-percent reduction in agricultural land.*

SMALL PRIVATE FOREST-LAND OWNERSHIPS

The 182,000 small forest-land ownerships (those of less than 5,000 acres of forest land) account for 53 percent of the total forest area in the State. Woodland owners[3] have been providing much of the State's timber products output during the past two or three decades and *could* be a major source of future supplies.

[3] *Throughout this paper the term "woodland owner" will be used only in reference to individuals possessing less than 5,000 acres of forest land.*

General Characteristics

The average size of ownership is 60 acres of forest land. However, the average is much smaller — 20 acres — for the 127,000 ownerships in the southern half of the Lower Peninsula, where wooded tracts generally occur on farms and represent a small portion of land that was never cleared for agriculture. Farther north where forest cover predominates, agricultural land, if present at all,

KENT COUNTY, MICHIGAN

1955 1960

FIGURE 3. — Rural land use changes in Michigan are often quite subtle. But there are times when the rural terrain is modified to a considerable extent. These two aerial photos, taken of approximately the same area at a 5-year interval, demonstrate how highway construction can greatly modify forest land. One woodlot shown (X) has been so dissected that it may never again support a timber harvest. (Photo courtesy U.S. Agricultural Stabilization and Conservation Service.)

usually accounts for a minor part of an individual ownership. Here the average size of ownership for the 55,000 woodland owners is 148 acres of forest land.

Although woodland owners are usually referred to in a collective manner, this ownership group represents a very diverse assortment. This can be shown by examining various characteristics such as occupation, length of tenure, age, and place of residency.

Owner's Occupation

Woodland owners show a variety of occupational backgrounds, with no single grouping comprising a majority (table 4). The farmer group (both full- and part-time) accounts for the largest amount of forest area, with the businessmen-professional owners running a close second.

Occupational patterns are fairly uniform throughout the State, but there are some significant differences. For instance, as one might expect, farmer-owners are not as prevalent in the Upper Peninsula as elsewhere in the State. Recreational groups own an insignificant amount of land in the southern half of the Lower Peninsula, but in the more northern forest zone, particularly the northern half of the Lower Peninsula, this group owns large areas. When one considers the objective of ownership (discussed later), recreation as a motive for owning forest land is even greater than the data on occupation tend to indicate, since many of the nonrecreation ownerships are owned mainly for outdoor recreation purposes.

Length of Tenure and Planning Horizons

Because of the long time required for timber products to mature, planning horizons of the individual owner and the stability of ownership are critical. An owner's plans and expectations for managing his forest land are influenced by how long he will hold his property. Indications are that the planning horizons for most owners were quite short (relative to the length of timber production periods) when they purchased or otherwise assumed control of forest land. Two-thirds of the area has been held by the present owners 20 years or less as shown below:

	Percent of woodland area held by present owners for—		
	1-10 yrs.	*11-20 yrs.*	*21+ yrs.*
Upper Peninsula	29	42	29
Lower Peninsula:			
North half	38	21	41
South half	37	39	24
Entire State	36	30	34

TABLE 4. — *Distribution of number of woodland owners and their forest acreage by occupation (In percent)*

Occupation	Upper Peninsula		North half Lower Peninsula		South half Lower Peninsula		Entire State	
	Owners	Forest area	Owners	Forest area	Owners	Forest area	Owners	Forest area
Farmer	17	13	39	21	20	24	22	19
Part-time farmer	-	-	12	9	11	11	10	7
Forest industry	3	6	*	2	*	*	1	3
Nonforest industry	1	8	*	[1]/5	*	1	*	5
Business-professional	10	22	5	15	13	20	12	18
Wage-earner	19	9	32	11	16	15	18	12
Housewife (widow)	13	14	6	8	5	7	6	10
Recreation group	6	6	1	13	*	1	1	7
Undivided estate	2	1	*	3	2	4	2	3
Retired	10	10	3	4	13	14	11	8
Other	19	11	2	10	[2]/20	[3]/3	17	8

* *Less than 0.5 percent.*

1 *Approximately 63 percent of this area is in one ownership.*

2 *Primarily owners of less than 3 acres but more than 1 acre of forest land.*

Since the average owner is 54 years old, the above data suggest that he acquired his forest land at about 40 to 45 years of age.

Assuming that the average owner will relinquish his property at age 65, the most distant planning horizon for the average new owner is 25 years. If he possessed only poorly stocked or nonstocked land, forest investment opportunities would probably have little appeal. Unless he were planning to produce Christmas trees, he would probably not plant trees to satisfy income needs because he would be unlikely to maintain control long enough to harvest a timber crop. One might argue that planting trees would enhance the value of an owner's property. It is doubtful, however, that individuals planting trees would be able to recoup much of their investment should they sell their forest land before the growing stock reached merchantable size.

For the owner whose woodlot has sufficient growing stock to support periodic harvests, expectations and plans can be formulated with a greater degree of certainty. Timber stand improvement work, for example, would bring financial returns in a short period.

Family Ties in Ownership

Three-fifths of all woodland owners in Michigan acquired their property from someone outside of their immediate family (table 5). However, the purchase of forest land from relatives varied considerably by district; in the southern half of the Lower Peninsula it accounted for one-third of the forest land compared with only 4 percent in the Upper Peninsula. For one reason, many of the small ownerships, in the Upper Peninsula particularly, were part of larger lumber company holdings being liquidated. Such exchanges never occurred in the southern half of the Lower Peninsula except in the northern tier of counties. In the northern half of the Lower Peninsula most of the lumber company holdings had been liquidated one or two generations prior to the time most of the present owners took possession of their property.

If shifts in property ownership did not reverse established precedents for promoting timber growth, the relatively rapid turnover of forest land would not be much of a hindrance to forestry. But since the transfer of forest property is generally a non-family exchange, chances are lessened that the new owner's plans would coincide with those of the previous owner.

TABLE 5. — *Means by which owners acquired forest land*

(In percent of forest area)

Method of acquisition	Upper Peninsula	Lower Peninsula		Entire State
		North half	South half	
Purchase:				
From relatives	4	14	33	16
From nonrelatives	72	59	57	62
Inheritance	20	27	10	21
Other[1/]	4	*	0	1

* *Less than 0.5 percent.*

1 *Includes tax sale, foreclosure, debt settlement, and gift.*

Owner's Place of Residence

The bulk of Michigan's small forest ownerships is held by people who don't live on them. Only 38 percent of the forest area is owned by people living at the site. Owners residing more than 100 miles away account for 25 percent of the area. However, if just the southern half of the Lower Peninsula is considered the absentee owner is in the minority, although a strong minority, possessing 41 percent of the private forest area. Furthermore, in this area only an insignificant acreage (5 percent) is owned by individuals living more than 100 miles from their woodland.

A generation ago there were probably fewer absentee owners. But today many owners were born and raised on their forest property and have since moved to the larger cities of the Midwest. Such owners often retain their parents' "homestead" for sentimental reasons (fig. 4).

F-504528

FIGURE 4. — Idle farm land in northern Michigan planted to pine. Present owner was raised here but now lives in Detroit.

This increasing number of absentee owners has important implications to public administrators. Promotion of forestry assistance programs among absentee owners will probably require a different approach from that used for resident owners.

Timber Products Marketing Activity

There is little evidence of formal planning by owners of small forest properties in Michigan. Only a very few have forest management plans prepared by Cooperative Forest Management (CFM) service foresters, industrial foresters, or consultants. Despite this lack of formalized management, from a physical standpoint, these owners account for the largest segment of the State's timber producing potential. How they harvest and market timber products has an important bearing on the productivity of Michigan's forest lands.

Frequency of Timber Sales

The relatively short span of years that most woodland owners hold their property has already been emphasized. Of course, accompanying and often directly associated with the shifts in ownership are the changes in the forest resource itself. Some owners liquidate their growing stock prior to selling property. Therefore, many new owners acquire nonstocked or poorly stocked land and will never see the day when their forest supports enough merchantable growing stock to attract timber buyers.

Actually, only a small proportion — 3 to 4 percent — of the owners do any timber marketing during a given year. Furthermore, less than half of the owners interviewed had ever sold timber products at all. There are various reasons for this. The most common is that the owner does not have any merchantable growing stock.

Owner's reason for not selling timber products	*Percent of forest owners*	
	Upper Peninsula	*South half Lower Peninsula*[1]
Had no salable timber	60	52
Had not received any offer for timber	4	17
Had not received any suitable offer for timber	(2)	15
Would be incompatible with other uses or values	7	8
Returns from sale would be negligible — not worth time or effort	2	3
No special reason	16	0
Other	11	5

[1] *No data available for northern half of Lower Peninsula.*

[2] *Not listed separately on questionnaire.*

Absentee ownership apparently influences the marketing of timber products. Of the owners who lived in the Upper Peninsula 53 percent had harvested timber products compared with only 11 percent of the absentee owners. Furthermore, the tabulation above shows that 17 percent of the owners in the southern Michigan area who had not sold timber products had never received offers for timber; most of these were absentee owners.

A minority of the owners indicated that logging would be incompatible with other uses or values (usually aesthetic). With the popularity of outdoor recreation intensifying, the number of "vacation owners" of forest land is bound to increase. Conceivably this could lessen the future supply of timber since it is usually this type of owner who finds logging incompatible with other uses.

In the Upper Peninsula and the northern half of the Lower Peninsula forest land often provides seasonal work for the woodland owner. In fact, some of the owners in these two areas are full-time timber producers or loggers. As a result, most of the harvesting activity in these areas was either for home use or sale of cut products; stumpage sales accounted for only a small portion of the timber harvesting activity.

Unlike the situation in the northern zone, logging is a forgotten art among the private forestland owners in the southern half of the Lower Peninsula. Two-thirds of those who harvested timber sold stumpage rather than did their own logging. What is more, only 9 percent of the owners who did not do their own logging supervised the logging operations.

Cutting Practices

Logging operations provided an opportunity to evaluate the level of forest management being practiced. Judging from the findings in the Lower Peninsula, the management of most small private holdings in this area does not improve the productivity of forest land (table 6). In both of these areas "poor" cutting practices were more prevalent than "good."

Some owners apparently did not realize that the loggers were going to harvest as heavily as they eventually did; however, the high incidence of fair to poor cutting practices generally stems from an owner's desire to liquidate all merchantable

TABLE 6. — *Cutting practices of owners who harvested timber during 5-year period prior to interview*[1]

Cutting practices[2]	Percent of owners harvesting timber		Percent of forest land owned by owners harvesting timber	
	N½ Lower Peninsula	S½ Lower Peninsula	N½ Lower Peninsula	S½ Lower Peninsula
Good	15	18	23	29
Fair	25	41	31	38
Poor	60	41	46	33

1 *No data available for Upper Peninsula.*

2 *"Good" cutting means that as a result of the logging activity a woodland will improve in quality and volume productivity within the first 10 years after harvest. "Fair" means that the stand will only maintain its precutting productivity during the 10 years subsequent to harvesting, while "poor" cutting means that the stand's productivity was reduced by logging.*

growing stock. For example, in the northern half of the Lower Peninsula 71 percent of the owners who had harvested timber intended that everything merchantable be harvested. In the southern half, 34 percent of the owners selling timber showed these intentions.

Timber Sale Administration

Most woodland owners who sold timber products did so in a rather unbusinesslike manner. Few realized that to harvest all merchantable growing stock often resulted in the removal of many trees at a stage where annual value growth was very high. Even if they had known this, many undoubtedly would have harvested it all anyway. As we shall see later, many owners were indifferent to forest management programs after having them explained.

Some owners did restrict cutting to certain diameter classes. In the northern half of the Lower Peninsula, for example, owners of about a quarter of the land cutover specified a limitation, while 14 percent marked trees for cutting. In the southern half of the Lower Peninsula, about 20 percent of the owners harvesting timber marked trees for cutting while 40 percent specified either a species or a diameter limit. In the latter instances (species or diameter limit), cutting practices were seldom improved because the cutting limit coincided with the merchantable limits. Only the act of marking trees for cutting led to improved stand conditions.

Owner's Knowledge of Markets and Prices

In the northern forest zones market and price information can be readily obtained. Often an inquiry at the nearest general store or filling station is all the effort it takes to learn the local market situation for wood products or stumpage. Many of the owners in these areas are part- or full-time timber operators with a good knowledge of markets and prices. Furthermore, much of the wood harvested in the northern area is pulpwood, a highly standardized product with a fairly stable price structure (fig. 5). As a result, most (89 percent in the Upper Peninsula) of the sellers of either cut timber products or stumpage in the northern areas generally feel that sources for market and price information are quite adequate. However, this does not rule out the need for better means to disseminate this type of data. Many of the nonsellers, particularly the absentee owners, might welcome such information.

In the farm woodlot area of the southern half of the Lower Peninsula nearly all of the timber harvested is saw logs. Unlike pulpwood, saw logs represent a very heterogeneous, nonstandardized product. Timber marketing in southern Michigan can be likened to horse trading in the sense that each transaction is unique, and the negotiated per-unit price depends largely on the buyer's and seller's relative knowledge of timber prices. Unfortunately, most owners in the southern areas have little knowledge of, let alone contact with, the market for timber products.

One indication of the seller's bargaining position in southern Michigan is the fact that 55 percent of the owners who sold timber had no real basis for judging the reasonableness of the prices received. Another 8 percent of the owners had professional advice, while the rest obtained price information from a friend or else compared different buyer quotations (usually only two). A significant proportion of the owners interviewed (47 percent) expressed interest in a public timber price and market information service.

FIGURE 5. — Pulpwood being trucked to a paper mill — a common sight in northern Michigan. F-504584

Woodland Improvement and Tree Planting Efforts

So far the discussion of Michigan's woodland owners as timber producers has concerned only the acts of harvesting and marketing. Technically speaking, these acts merely represent the culmination of the long-term process of timber production. With most crops there would be no harvest unless input factors were introduced at various stages in the production process before harvesting, but in forests a crop of some sort can be brought to maturity without positive effort. Actually, there is little reason to doubt that most of the timber products from the State's small private forests are produced with little or no husbandry on the part of the owner. In both the Upper Peninsula and the southern half of the Lower Peninsula only 5 or 6 percent of the respondents indicated that they had conducted woodland improvement practices.

When one considers that some of this timber stand improvement dates back as far as 20 years, and that much of it was carried out on just a portion of the owner's property, the insignificance of such effort becomes apparent. Obviously not enough has been done to offset the detrimental effect of poor cutting practices, which have downgraded species composition and age-class distribution.

Tree planting is much more popular among the woodland owners than timber stand improvement. In the southern half of the Lower Peninsula 20 percent of the owners had planted trees, while in the Upper Peninsula about 7 percent of the owners had done so. Data are not available for the northern half of the Lower Peninsula, but planting here is more widespread than in the other regions. Stone and Chase (1962) estimated that between 1900 and 1956 private owners planted nearly 168,000 acres of trees in this area.

In the Upper Peninsula the acreage of plantable sites is small. In any case, many of the present owners had worked hard to clear forest land for farming; whether or not this land has since been idled, most of these owners aren't about to turn around and plant trees on it.

Average size of forest plantations established by woodland owners in both the Upper Peninsula and southern Michigan areas was between 6 or 7 acres. When one considers the limited acreages involved and the fact that many of the owners did not plant their trees for timber production purposes, it becomes apparent that tree planting by woodland owners, like timber stand improvement, has not contributed much to the productivity of the forests in these two subregions of the State. In the northern half of the Lower Peninsula tree planting by the small private owner has probably made a more significant contribution.

Owner's Recognition of the Need for Improved Forest Management

The prevalence of poor cutting practices and the lack of interest in timber stand improvement and tree planting reflect the owners' lack of concern for the productivity of their forest land. Simply stated, many of them do not believe that any improvement is needed on their forest land. This lack of concern is most apparent in the northern forest zone of Michigan where more than half of the respondents indicated that no improvement was needed (table 7). But in the southern half of the Lower Peninsula about two-thirds of the owners believed that woodland management should be improved.

This indifference of so many owners toward management for timber production is a manifestation of many complex, interrelated factors. Infrequent and often trifling incomes from the forest, the long-term process of timber production, limited planning horizons, more lucrative alternative uses for time and money, limited concepts of forest management — all these and other factors contribute to apathy toward forestry. It might be asked then, "If the owners are not interested in timber production, why are they holding forest land?" There are many answers.

Only 3 percent of the State's small forest-land owners are making a conscious effort to grow timber for sale or use (table 8). Most of these owners have had professional guidance from a forester (mostly CFM foresters), and all are managing their timberland on a sustained yield basis. But some other owners are maintaining their forest property primarily on account of timber values. Twenty percent gave "farm and/or home use" as the reason for owning their forest land, while another 4 percent keep it because of plans to liquidate mature growing stock when they have enough to attract buyers. However, only those

TABLE 7. — *Owner's recognition of the need for improved forest management (Percent of owners)*

Owner's response	Upper Peninsula	Lower Peninsula		State
		North half	South half	
Does not believe any improvement needed	52	56	24	35
Believes woodland management needs to be improved	48	43	76	65
No opinion	0	1	0	*

* *Less than 0.5 percent.*

TABLE 8. — *Percentage of owners with various objectives of ownership of forest land*

Objective of ownership	Upper Peninsula	Lower Peninsula		State
		North half	South half	
Farm and/or home use	17	[1] 37	17	20
Pasture	2	([2])	11	8
Fuelwood	2	([2])	6	4
Growing timber for sale or use	0	4	4	3
Liquidation of mature growing stock	4	*	23	16
Investment or speculation	6	4	3	4
Clear for agriculture	0	6	5	4
Recreation	26	39	4	18
Residence	19		2	
Inactive	14	9	19	17
Other	10	1	6	6

* *Less than 0.5 percent.*
1 *Includes "pasture" and "fuelwood" objectives.*
2 *Included with "farm and/or home use" objective.*

owners who are "growing timber for sale or use" are managing their timberland on a sustained-yield basis.

For the majority of the owners, benefits from timber production — sustained or otherwise — are not the reason for holding forest land. Eighteen percent keep it for a residential or recreation site, and some of these people would find timber production incompatible with their main objective (fig. 6).

Because of the psychic values associated with landownership, forest land has become a consumption as well as a production good. This situation is more pronounced in the northern counties than in southern Michigan (table 8). As previously pointed out, to the extent that the number of "recreation"

F-504583

FIGURE 6. — This sign and single strand of wire mark the boundary of a hunting club in northern Michigan. The single wire legally is a fence and anyone caught trespassing may be prosecuted. An increasing area of forest land is owned by individuals and groups interested primarily in reserving hunting rights.

and "residential" owners of forest land does increase — and with leisure time and better transportation facilities becoming more abundant, it would seem logical to expect such increases — timber production might well become incompatible with the objectives of a larger segment of the small-owner population. Certainly it is a vital issue to consider when projecting future timber supplies.

In the southern half of the Lower Peninsula, urban encroachment of forest land will continue to hamper the flow of timber products. During the first decade after World War II, the annual rate at which forest land shifted to nonforest uses in this area was estimated to be about 1.4 percent. That building boom is over, but cities are still expanding. One interesting aspect of expansion is that individuals living in the "urban fringe" (usually the first tier of townships surrounding a city's corporate limits) are less likely to harvest timber than owners elsewhere; this suggests that forest land ceases to be a potential source of timber before physical encroachment by urban uses. So, like the "recreation-residential" owner, the woodland owners residing in the urban fringe tend to reduce the economic supply of timber products from Michigan's forests.

Interest and Participation In Forest Assistance Programs

During the last three or four decades, particularly during the 1930's, several public-sponsored forestry assistance programs have been inaugurated. Although the approaches may differ somewhat between programs, the basic underlying premise for all of them is that a level of forest conservation deemed optimum from society's standpoint will not be implemented by the majority of woodland owners without outside assistance — technical, monetary, or both.

Assistance Programs Take Varied Forms

The oldest assistance program is forestry extension, which was authorized by the Clarke-McNary Act of 1924. This Act provides for educational assistance to owners of farms in establishing, renewing, protecting, and managing woodlots, shelterbelts, and windbreaks, and in harvesting, utilizing, and marketing the products from woodland areas.

No other assistance program attempts to reach as many people as forestry extension. As with other phases of the cooperative extension program, the County Agricultural Extension Director's office is the point from which much of the forestry extension information and aid is disseminated. With cooperation of the Federal Extension Service and the technical guidance of two extension foresters — one at East Lansing serving the Lower Peninsula and the other at Marquette serving the Upper Peninsula — Michigan's County Agricultural Extension Directors prepare and use newspaper articles, radio talks, circular letters, or other means to stimulate forest conservation. Forestry field days are planned in areas where owners indicate an interest.

On-the-ground public assistance to individual owners is handled by the Cooperative Forest Management (CFM) foresters. The Cooperative Forest Management Act of 1950 authorized the Federal government to cooperate with the States in providing technical service to private forest-land owners

and operators and to processors of primary forest products. This Act superseded the Norris-Doxey Act of 1937, which was similar but restricted assistance to farmers only.

Department of Conservation district foresters are responsible for providing CFM assistance statewide. However the amount of time spent on this activity varies considerably from area to area. Because of the relatively light demand for CFM aid, district foresters in the Upper Peninsula devote only about 5 to 6 percent of their time assisting private landowners. The bulk of their time is spent managing public lands. In the northern half of the Lower Peninsula, about 25 percent of the technical time is devoted to CFM work, and in southern Michigan 90 percent. Since the manpower assigned to the two northern districts is about three times that of the southern zone, the disparity in time devoted to CFM activities is not as great as the precentages imply. The following tabulation shows how much Conservation Department manpower was devoted to the CFM program during the 1961-62 Fiscal Year:

	Man-years
Upper Peninsula	1.5
Lower Peninsula	
Northern half	6.0
Southern half	7.2
Total	14.7

Although Federal financing of CFM activities for the Upper Peninsula was not utilized until 1957, Department of Conservation foresters provided this service at State expense prior to that time.

Forestry plays an important role in the Soil Conservation District Program. The Soil Conservation Districts (SCD), which are governmental subdivisions of the State operated and controlled by land occupiers, provide a means by which farmers and other landowners can organize to protect their soil and water resources. The Soil Conservation Service provides technical assistance. Where appropriate, forestry measures are included in the farm plan. For example, such a plan may call for a reduction or increase in woodland area. Under a written Memorandum of Understanding with the Soil Conservation Service, the Forestry Division of the Michigan Department of Conservation, when needed, provides technical assistance to Soil Conservation District cooperators.

All but 10 of Michigan's 83 counties are organized into Soil Conservation Districts. Soil Conservation Service technicians are available to assist landowners outside of the district boundaries.

In addition to the informational services of the forestry extension program and the on-the-ground technical assistance provided by the Soil Conservation District and the CFM Program, Michigan's small forest-land owners can get financial aid for carrying out certain conservation practices through the auspices of the Agricultural Conservation Program (ACP). Tree planting has been the most popular forestry practice promoted by ACP, but various timber stand improvement practices are gaining rapidly both in recognition by Agricultural Stabilization and Conservation Service (ASCS) personnel and in acceptance by the landowner. An owner applying for cost-share payments must have the proposed practice certified by a Conservation Department District forester before payment is authorized. Generally, the owner is reimbursed for about half the cost.

Response to Assistance Programs Varies

Generally speaking, participation in forestry assistance programs has been minimal. However, participation and interest vary somewhat depending upon the program and the area of the State.

Most of the owners in the southern half of the Lower Peninsula were familiar with farm-practice aspects of the ACP. Many had received cost-share payments for carrying out nonforestry conservation practices, but few knew of or had participated in the forestry phase. Owners of only 6 percent of the area's small private forest land had received forestry cost-share. However, another 10 percent of the owners previously not familiar with forestry ACP indicated some interest in such assistance after it was explained to them. With additional exposure to the program many of these owners would probably apply for ACP cost-share to improve their woodland management. Owners of most of the forest land (84 percent) said they would not be interested.

Even fewer woodland owners of southern Michigan had participated in the forestry extension program than in the ACP program. Owners who had had extension aid accounted for only 1 percent of the forest land, but owners of 19 percent of the forest area showed some degree of interest after the extension program was explained to them.

One out of 10 woodland owners in southern Michigan had a Soil Conservation District farm plan, but only a minority of these "planners" had adopted forestry practices. Twenty-five percent of all planners did "retire" some cropland or grassland by planting trees.

Judging from the response to questioning, the CFM Service Forestry Program has the most appeal to woodland owners in southern Michigan. Owners who had received CFM aid accounted for 8 percent of the area's privately owned forest land, while another 8 percent of the forest area was owned by individuals who knew of and expected to ask for CFM aid in the future. In addition to these two groups, "interested" owners accounted for 28 percent of the forest area. These present and potential CFM clients own 57 percent of the value of the merchantable growing stock in southern Michigan.

Since most of the owners who sought CFM forestry aid did so when they were trying to sell stumpage, it was possible to obtain some indication of the effectiveness of the CFM Program. A comparison of cutting practices showed that almost 60 percent of the owners receiving CFM aid practiced good cutting versus only 13 percent of the nonparticipants.

In the northern half of the Lower Peninsula aid from both ACP and forestry extension was greater than from CFM. Owners of 11 percent of the small private forest land in the northern half of the Lower Peninsula had received ACP forestry cost-share while owners of another 8 percent of the forest area exhibited some degree of interest. Recipients of forestry extension assistance accounted for 16 percent of the area's forest land, and another 27 percent of the woodland was owned by persons interested in such aid.

Owners who had received CFM aid accounted for a smaller share of the land in small ownerships (9 percent) than owners participating in ACP or extension programs. But once the opportunities of the various programs were explained, CFM had the most appeal to the "uninitiated" interviewees. This interested group accounted for 61 percent of the area's small private forest land. Because additional exposure to this program would probably stimulate more actual participation, and because promotion of the CFM Service Program has been stepped-up considerably in the northern half of the Lower Peninsula since this information was gathered, a reassessment would undoubtedly disclose more participation.

The prevalence of SCD cooperators was about the same in the northern half of the Lower Peninsula as in the southern half. Owners of approximately 10 percent of the small private forest land in the northern half had farm plans. As in southern Michigan, few cooperators had adopted forestry practices as a result of the SCD plan. Of those who did, most stated that they had planted trees.

While a significant number of Upper Peninsula woodland owners were familiar with the availability of technical on-the-ground assistance — 21 percent of them knew that advice could be had while an additional 18 percent could cite a specific source — only 12 percent received such aid. The bulk of assistance in such instances came from State foresters (3 percent of owners) and Soil Conservation Service personnel (also 3 percent). County agents and the extension forester also helped 3 percent of the owners. Most of the advice concerned tree planting, but about a fourth of the owners asked for aid in timber harvestng.

Only about 3 percent of the Upper Peninsula owners had applied for forestry ACP cost-share payments, and even fewer were interested after it was explained to them. Almost all of those receiving ACP assistance did so in connection with tree planting operations.

Other Forestry Programs Are Available

In addition to public assistance programs a number of private agencies are at work. One is the American Forest Products Industries (AFPI) Tree Farm Program. Designation as a "Tree Farmer" serves as public recognition of an owner's voluntary commitment to practice good forestry (fig. 7). There are no membership dues, no subsidies or assessments. Much of the emphasis has been directed toward owners of more than 5,000 acres. As of August 1962, 885 woodland owners had been designated as Tree Farmers in Michigan. They owned 138,150 acres of forest land.[4] Many small owners are aware of the program, but few knew the qualifications. Most of the owners who had participated felt that their attitude toward forest conservation was enhanced by the association with the Tree Farm Program.

Some AFPI-member companies have established their own programs under which they will provide technical service to woodland owners under contract for purchase of timber products.

[4] *Letter from James C. McClellan, Chief Forester for American Forest Products Industries.*

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FIGURE 7. — Nearly 900 Michigan woodland owners have been designated Tree Farmers.

Private consulting foresters have aided some of Michigan's woodland owners. Five forestry consulting firms are headquartered in Michigan, two of which restrict their activities to the Upper Peninsula. Judging from the limited interest shown by landowners, the potential for expanding customer service to small woodland owners is quite limited. Less than 1 percent of the owners in the southern half of the Lower Peninsula expressed interest in hiring a consulting forester to help manage their forest property. In the Upper Peninsula a somewhat larger proportion, 6 percent, was interested.

Owners were also queried as to their interest in cooperative agreements whereby they would join with other woodland owners in hiring a forester to manage their forest properties. This idea had very little appeal to owners in the Lower Peninsula. In the southern half only 5 percent and in the northern half 1 percent of the owners expressed an interest. On the other hand, a fairly large number of owners in the Upper Peninsula were attracted by the suggestion — 14 percent of the owners with 32 percent of the land. This difference is partly accounted for by differences in ethnical backgrounds. A higher proportion of persons of Finnish background live in the Upper Peninsula, and cooperatives have long been a part of the national way of life in Finland.

Influence of Credit and Taxation On Forest Management

It has often been suggested that if low-cost credit were available more woodland owners could be encouraged to practice forestry. Of the owners questioned on this subject, 12 percent in southern Michigan, 7 percent in the northern half of the Lower Peninsula, and even fewer in the Upper Peninsula were interested in forest credit. If profitable forestry investment were shown to exist, perhaps more owners would be interested.

The idea of forest credit sounds good. It could serve as a means of reducing the pressure on forest owners to liquidate their timber capital when they needed ready cash — for example, when one heir is trying to buy out the interests of others. But since most woodland owners are indifferent toward forest credit, lending institutions would have a task trying to stimulate a demand for loans secured by forest real estate.

Action has been taken in the past to reduce the financial strain brought about by another institution — the *ad valorem* property tax. Michigan has two forest yield tax laws: The Woodlot Yield Tax Law and the Commercial Forest Reserve Act, both designed to shift the incidence of tax on forest property from periods when no income is being derived to occasions when harvest cuts are made. Hence, the name "yield tax."

About 475,000 acres of Michigan's forest land has been registered under the Commercial Forest Reserve Act. However, all but about 18,000 acres of it is in holdings of more than 5,000 acres. Less than 60 woodland owners have listed forest tracts under this Act.

No centralized records are maintained on the Woodlot Yield Tax, so it was not determined how much use has been made of it. It is generally believed that the few properties that have been listed are nearly all located in southern Michigan.

Only about 50 percent of the area classified as small ownerships qualifies for registration under

either of the yield tax laws.[5] As shown below, the percent of holdings that qualify is quite uniform throughout the State.

	Percent of forest area
Upper Peninsula	46
Lower Peninsula:	
Northern half	58
Southern half	45
Average for State	51

When questioned, less than 10 percent of the owners in the Upper Peninsula and the southern half of the Lower Peninsula were familiar with either law. Owners of 72 percent of the forest land in the northern portion of the Lower Peninsula said they were unfamiliar with the tax laws.

None of the interviewees in the Upper Peninsula or southern Michigan area had registered their forest land under the Woodlot Yield Tax Law or the Commercial Forest Reserve Act, and only 1 percent of the owners had done so in the northern half of the Lower Peninsula. Therefore, it was not possible to appraise the effect these laws had on forest management. All owners who had registered forest land under these laws, however, indicated that the action did not affect their forest management activity.

Owners who were familiar and qualified, but had not registered land, gave a variety of reasons. Some felt that if they did, assessments would be raised on other property to make up for the loss of tax.

Despite the fact that few owners had taken advantage of forest yield tax laws and only a small percent were interested after it was explained to them, the laws have some effect. They serve to moderate assessments where an increase might prompt owners to use them.

[5] *To qualify for the Woodlot Yield Tax a wooded tract must not be more than one-fourth of a parcel of land 160 acres or less in size, of which at least 50 percent is improved and devoted to agriculture. If stocking specifications are not naturally met the tract must be planted. Also, woodland grazing is not allowed. To qualify for the Commercial Forest Reserve Act no portion of a wooded property may be devoted to agriculture, grazing, industrial, recreational, or resort purposes. The land must be classified as commercial forest land but cannot be overstocked with mature timber at the time of application. The stocking must meet certain specifications, and no restriction on public hunting or fishing on the property is allowed.*

Woodland Owners a Heterogeneous Lot

It is well understood that the woodland owners are a very heterogeneous grouping of individuals. Often, however, too easy generalizations are made for the entire group. True, most of the owners are indifferent toward forestry practices, most own their forest land for reasons other than timber production, and most have not participated in assistance programs. Nevertheless, certain distinctions should be recognized, particularly if the goal is to achieve more participation in forestry assistance programs.

We often hear reference to "farm woodlot" owners, when in reality the farmer group accounts for only a minority of the small holdings. But even here the situation varies from one section of the State to another. The farmer category owns proportionately more forest land in the Lower Peninsula (approximately one-third of the area) than in the Upper Peninsula (13 percent of the forest area). Failure to recognize these occupational differences has probably dampened the effectiveness of assistance programs in the past, since most information is channeled to the farmer group.

Absentee ownership, which also exhibits considerable variability in Michigan, is another factor in reaching the woodland owners with assistance programs. In the past, publicity has been mainly directed toward the resident owner. In southern Michigan, where absenteeism is not very prevalent, the consequences may be slight, but for the remainder of the State increased efforts to reach the absentee owner would seem justified.

Interviewees cited many reasons for owning forest land, and again this varied throughout the State. Although few gave timber production as their reason, some of the nontimber production motives might be more compatible with increased forest product output than others. In other words, steps to encourage increased timber production among the nontimber producers should probably take various forms depending upon characteristics such as the owner's objective of ownership and alternative uses for time and money. Lastly, of course, there is the matter of size. The term "small ownerships" covers a wide range of sizes from very small holdings of a few acres up to 5,000 acres. In the past forestry assistance has been administered indiscriminately of size of an applicant's forest holdings. It would seem that there is merit in directing more time and effort toward the larger small ownerships.

LARGE PRIVATE FOREST-LAND OWNERSHIPS

Approximately 3 million acres of private commercial forest land in Michigan are in ownerships of 5,000 acres or more. This is more large private forest acreage than in the two other Lake States combined. Most of it is in the Upper Peninsula. Only 11 percent lies south of the Straits of Mackinac.

The 3 million acres are divided among approximately 57 ownerships and average about 55,000 acres in size. These figures contrast sharply with the 180,000 small ownerships with an average of 60 acres apiece. As shown below, better than two-thirds of the large forest ownership is held by 10 owners having 100,000 acres or more each.

Area size-class (Acres)	*Number of owners*	*Percent of forest area*
5,000 — 25,000[1]	31	12
25,001 — 50,000	10	10
50,001 — 100,000	6	13
100,001+	10	65
Total	57	100

[1] *The number of owners in the 5,000-25,000 class is an approximation. There are probably a few more owners with 5,000 - 10,00.. acres of forest land. Such ownerships are difficult to locate from county records and plat books because they are usually made up of many scattered holdings.*

Half of Large Ownership Area Owned by Forest Industry

Individuals owning more than 5,000 acres of forest land are the exception rather than the rule; they account for only 3 percent of the forest area in large ownerships (table 9). The remainder of the large ownerships represent various sorts of corporate agencies. Ownership patterns differ considerably between the Upper and Lower Peninsulas. At the State level forest industries account for 46 percent of the large forest ownership area, but they own only 7 percent of the area in the Lower Peninsula. Recreational groups, which have only a small segment (3 percent) of the Upper Peninsula's large forest ownership area, have 31 percent in the Lower Peninsula and are the second largest single group of owners in terms of forest area. The largest is the nonforest industry group with 48 percent of the area.

The dearth of forest industry holdings in the northern half of the Lower Peninsula resulted from cut-out-and-get-out tendencies of the early loggers. After logging and forest fires had depleted growing stock levels, timber barons were no longer interested in maintaining ownership of their lands. In contrast, logging of old-growth timber in the Upper Peninsula was more gradual and fire history less severe. Also, being more isolated and less desirable for farming, the Upper Peninsula has never experienced much change resulting from agricultural production and the accompanying land clearing and fragmentation.

Large Ownerships Exhibit Stable Tenure

Short tenure probably inhibits the promotion of better forestry on the part of the woodland owner. In contrast the large corporate ownerships display very stable tenure. Approximately 85 percent of the large owners (possessing the same percentage of the forest area in large ownerships) have ownership ties dating back at least 20 years.

TABLE 9. — *Large private forest-land ownerships by type of ownership (In percent)*

Type of ownership	Upper Peninsula		Lower Peninsula		State	
	Owner	Area	Owner	Area	Owner	Area
Individual	8	2	7	9	8	3
Forest industry	50	51	7	7	39	46
Nonforest industry	17	27	20	48	17	29
Recreation groups	7	3	53	31	19	6
Other	18	17	13	5	17	16

Length of tenure (years)	*Percent of forest owners*	*Percent of forest area*
0-20	14	14
20-40	30	33
40+	56	53

More than half of the owners have had their forest property for at least 40 years. In fact, several of the ownerships date back to the 1890's.

The *number* of large forest-land ownerships has been decreasing in Michigan, but the reasons for this vary between the Upper and Lower Peninsulas. In the Upper Peninsula large ownerships have been consolidated. In the Lower Peninsula there has also been some consolidation, but the trend is toward more fragmentation of large forest ownerships. Since the 1930's several have been divided up and sold to individuals.

Reasons for Owning Forest Land Differ

Owners of large forest areas, like small owners, have various reasons for holding forest land. Unlike the small owner, however, the majority, 51 percent, are interested primarily in timber production (table 10); they own 60 percent of the forest land. Another 6 percent of the owners, accounting for 20 percent of the land, hold forest land for both timber production and recreation.

Again a contrast between Upper Peninsula and Lower Peninsula owners is apparent. The objective of 60 percent of the owners in the latter area is recreation. Most are hunting clubs. In the Upper Peninsula only 7 percent of the owners have a recreation objective. Stated the other way, only a small minority of the Lower Peninsula owners maintain their forest land primarly for timber production, whereas most of the present owners in the Upper Peninsula (65 percent) do.

Management of Forest Land Often Geared To Sustained Timber Production

Prior to World War II, very little forestry was practiced in Michigan on private lands. Only a few of the larger ownerships had industrial forestry staffs. Since the war, however, most of the industrial forest owners and several of the nonforest industries, recreational groups, and "other" owners have formed their own staffs or hired consultants. As shown below, about 84 percent of the large owner area is managed by professional foresters:

Number of foresters	*Large owners (percent)*	*Forest area (percent)*
None	44	16
1	15	6
2-5	27	50
6 or more	7	26
None, but obtains outside professional aid	7	2

Most of the forest land in large ownerships is being managed for timber production. More than half of the owners have management plans that guide timber harvesting on a sustained yield basis. These owners account for 83 percent of the acreage. Most, but not all, are forest industries.

TABLE 10. — *Primary objective or reason for holding large forest ownerships (In percent)*

Objective	Upper Peninsula		Lower Peninsula		State	
	Owners	Area	Owners	Area	Owners	Area
Timber production	65	66	7	7	51	60
Recreation	7	3	60	33	20	5
Timber production and recreation	7	22	-	-	6	20
Speculation	4	1	7	9	5	2
Inactive	2	3	7	3	3	3
Other[1/]	15	5	19	48	15	10

[1] *Includes watershed management, liquidation of growing stock, and mineral deposits.*

Not all of the management plans are elaborate, but some are very detailed. In the past some owners have found it difficult to maintain cutting levels within sustained yield limits, but by and large most owners who have management plans are endeavoring to maintain or increase their present level of timber growth. Nearly all of these owners also make periodic forest inventories. Those who do not have adopted cutting standards which spell out residual basal area limits.

In addition to plans and inventories, about a third of the owners have tree planting programs. Since much of their timberland is fairly well stocked, tree planting activities need not be extensive. About half of the owners who plant trees also conduct timber stand improvement operations.

No appraisal of cutting practices was made in connection with this report on Michigan's larger forest-land ownerships. However, it is possible to get some idea of the quality of logging from the Timber Resources Review. The TRR estimated that the productivity of recently cutover land owned by this group in the Lake States was comparable to that found on public forests (U.S. Forest Serv. 1958, p. 609). Since Michigan accounts for 63 percent of the large ownership area in the Lake States region, these findings are probably fairly representative of the situation in Michigan.

Large Ownerships Registered Under the Pearson Act

As mentioned earlier approximately 475,000 acres of forest land had been registered under the Commercial Forest Reserve Act (Yield Tax Law). Of this total, 96 percent is owned by individuals or corporations having 5,000 acres or more of forest land. The land entered by these owners represents about 15 percent of the large ownership area. Practically all of the entries are in the Upper Peninsula.

PUBLIC FORESTS

Michigan's public forests are lands that nobody wanted. As we shall see, most of the State and National Forest lands were formerly in private ownership but were forfeited by their owners for taxes.

Municipal and county governments own some forest land in Michigan, but the amount is insignificant. For this reason, only State and National Forests will be considered here.

State Forests

Although the State Forest system dates back to 1903, until the 1930's the acreage of forest land involved was less than one-tenth of its present size. As late as 1920 most of the area now in Michigan's State Forest system was still in private ownership. At that time only about a million acres of land was in State or Federal ownership, most of it located in the northern cutover counties (Barlowe 1948, p. 9).

When the Michigan Department of Conservation was organized in 1921, there were only about 275,000 acres of State Forest land. It was at this time, however, that large-scale reversion of tax-delinquent lands began. By 1933 the State Forests had increased to over 800,000 acres. A tax moratorium between 1933 and 1938 stemmed the flow of private land to public ownership, but within a year after the moratorium was terminated 2.2 million acres reverted to the State. County land use planning committees tackled the monumental job of sorting this land to determine its proper use — whether to retain in public ownership or return to private hands. The larger part, 1.8 million acres, was retained and added to State Forests and State game areas.

The last significant addition to the State Forest System occurred in 1946, when 1.4 million acres of State-owned game areas in northern Michigan became State Forests.

Now 23 separate State Forests, ranging from 35,000 to over 300,000 acres each, make up the 3,765,000-acre State Forest System, the largest in the Nation (fig. 8). These lands are administered by the Forestry Division of the Conservation Department. An average of 62 percent of the gross area within the boundaries of the State Forests is State owned (table 11).

Timber Product Output From State Forests Is Increasing

Most of the State Forest area was not capable of supporting timber harvests until about 1941. Prior to that, the volume cut was negligible and consisted mostly of salvage material from windstorms and fires. Since the beginning of World

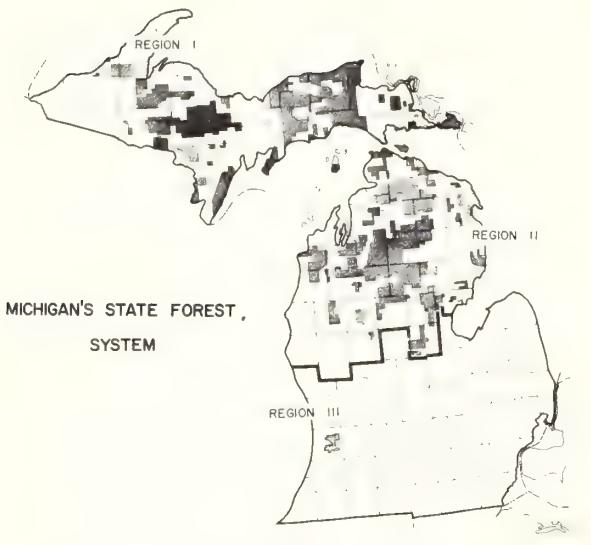

FIGURE 8. — Location of Michigan's State Forests. Of the 23 State Forests, 11 are located in the Upper Peninsula (Region I), 11 in the northern half of the Lower Peninsula (Region II), and 1 in the southern half (Region III).

War II, however, the harvest has increased rapidly (fig. 9). In 1941, for instance, the total volume of cut — all units converted to board feet — was 2.8 million board feet. In comparison, the 1960 cut was nearly 136 million board feet. Annual receipts from timber sales increased from $6,806 to $795,816 during the same period.

TABLE 11. — *Distribution of State forest land by region*

Region	Net State ownership	Gross area within State Forest boundaries	Percent State owned
I (Upper Peninsula)	1,848,593	3,085,377	60
II (North half Lower Peninsula)	1,884,267	2,953,849	64
III (South half Lower Peninsula)	32,558	47,160	69
Total	3,765,418	6,086,386	62

Source: Michigan Conservation Department, Twentieth Biennial Report, 1959-1960.

The increased sale of timber products is attributable mainly to more pulpwood cutting. Saw log cutting, which generally accounts for less than 10 percent of the annual volume, has remained fairly stable during the past 10 to 15 years. Pulpwood production, on the other hand, more than tripled between 1951 and 1960.

The State Forests make a significant contribution to the total output of timber products in Michigan. For example in 1957, 21 percent of the State's pulpwood harvest and 36 percent of its chemical and charcoal wood came from State Forests (Kearns et al. 1962, p. 7). However, of the State's saw log and veneer log volume output, only 4 percent and 6 percent, respectively, were accounted for by State Forests, which do not own much timber of saw log size.

Timber Sales Actively Administered

The private woodland owner has been described as a rather passive producer of timber products. From the ensuing two sections (as well as a comparable discussion pertaining to the National Forests), it will be apparent that the public forest managers play a positive role in marketing timber.

During the 10-year period 1951-1960, receipts from timber sales averaged about $550,000 annually. The number of sales varied from 1,500 to about 2,300 per year. Most of them involved payments of $500 or less.

Timber sales are handled differently depending upon the amount of money involved. If the sale involves less than $1,000 it may be made directly by the District Foresters without advertising. Sales involving $1,000 or more are called "public" sales and in addition to being advertised, they require approval by the Conservation Commission. Upon approval, stumpage is sold by auction or sealed bid. During the 1961-1962 biennium "public" sales accounted for only 8 percent of the permits issued on State forest land, but they accounted for 43 percent of the total receipts.

Cutting System Carefully Planned

Determination of the allowable cut for each of the State Forests is based upon continuous forest inventory in which each Forest is reinventoried every 6 or 7 years. At the time of reinventory identical plots are remeasured, and growth and drain are projected for the next 10 years. That

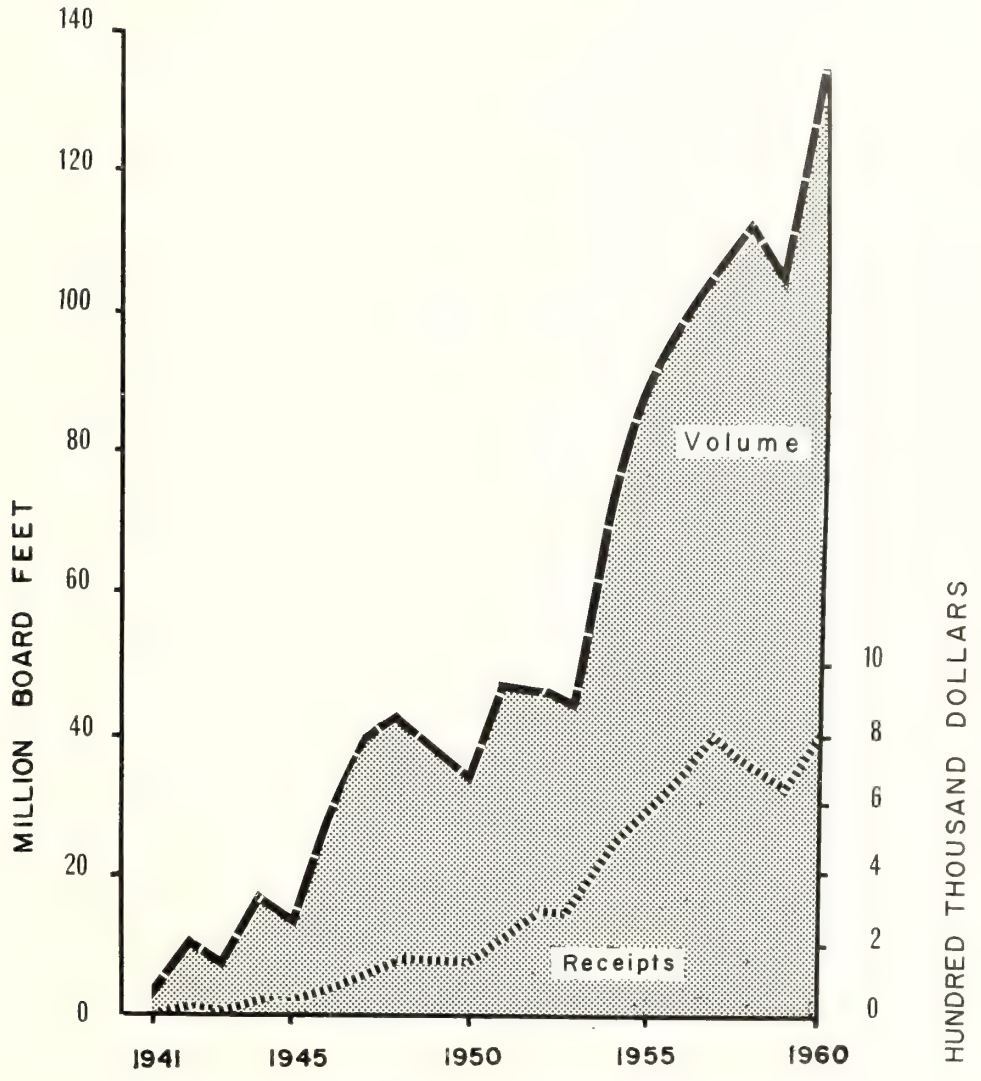

FIGURE 9. — Timber output from Michigan's State Forests, 1941-1960.

is, by rewriting management plans every 6 to 7 years the forest manager can assess progress toward a 10-year goal, at which time new goals are established for an ensuing 10-year period. Table 12 shows that for a 3-year period, 1959-62, the actual cut was somewhat below the allowable cut. For instance, in terms of cordwood material, the area was undercut by about one-third.

The Forestry Division's system for regulating the cut is based on area as well as volume control. Under this system each type within a forest is classified by "cutting period." The cutting period reflects the maturity class of the stand as indicated by age and condition. Five cutting periods are used in this classification scheme:

TABLE 12. — *A comparison of average annual allowable cut to average annual actual cut for State Forest lands of Michigan, July 1959 through June 1962.*[1]

Region	Annual allowable cut		Annual actual cut	
	Cords	Thousand bd. ft.	Cords	Thousand bd. ft.
I (Upper Peninsula)	162,985	10,240	121,578	4,361
II (North half Lower Peninsula)	197,395	5,175	116,229	4,959
State total	360,380	15,415	237,807	9,320

[1] *Cut from State forest lands in Region III was negligible.*

Period:
- I.— Mature and should be cut within 5 years.
- II.— Mature or near mature but not in danger of serious loss — cutting can be deferred 5 to 10 years.
- III.— Will reach maturity within 10 to 20 years.
- IV.— Will reach maturity in 20 to 40 years.
- V.— Will not reach maturity for at least 40 years.

Figure 10 shows schematically how the cutting period technique was utilized to compare actual area and volume for the jack pine type of the Thunder Bay River State Forest with optimum conditions and under full regulation. It points out, for instance, that a disproportionate area and volume of the type is in Period IV, and that if this is not corrected a greatly increased volume of jack pine may be expected to become available 20 to 40 years later. On the other hand, the area now in Cutting Period V is much smaller than regulation would dictate. Cutting Period III occurs in approximately the desirable quantities both as to area and volume, while Periods I and II combined cover approximately the desirable area but contain somewhat less than the desirable volume. Harvest of some of the Cutting Period IV volume and area within the next 10 years, along with Period I and II material, will thus tend to improve regulation for continuous yield. The sacrifice of volume growth resulting from harvest of immature timber must be considered in relation to the desirability of attaining improved regulation.

At the time of reinventory, the District Forester and Regional Foresters meet with timber management and survey specialists and determine the course of cutting in a particular State Forest, by types, for the next 10 years. However, it is the District Forester's job to delineate the cut by stands.

Reforestation Program Modified in Recent Years

Michigan's State Forest planting program dates back to 1904, but during the next 24 years less than 2,000 acres were planted annually. Planting on State Forest land did not commence in earnest

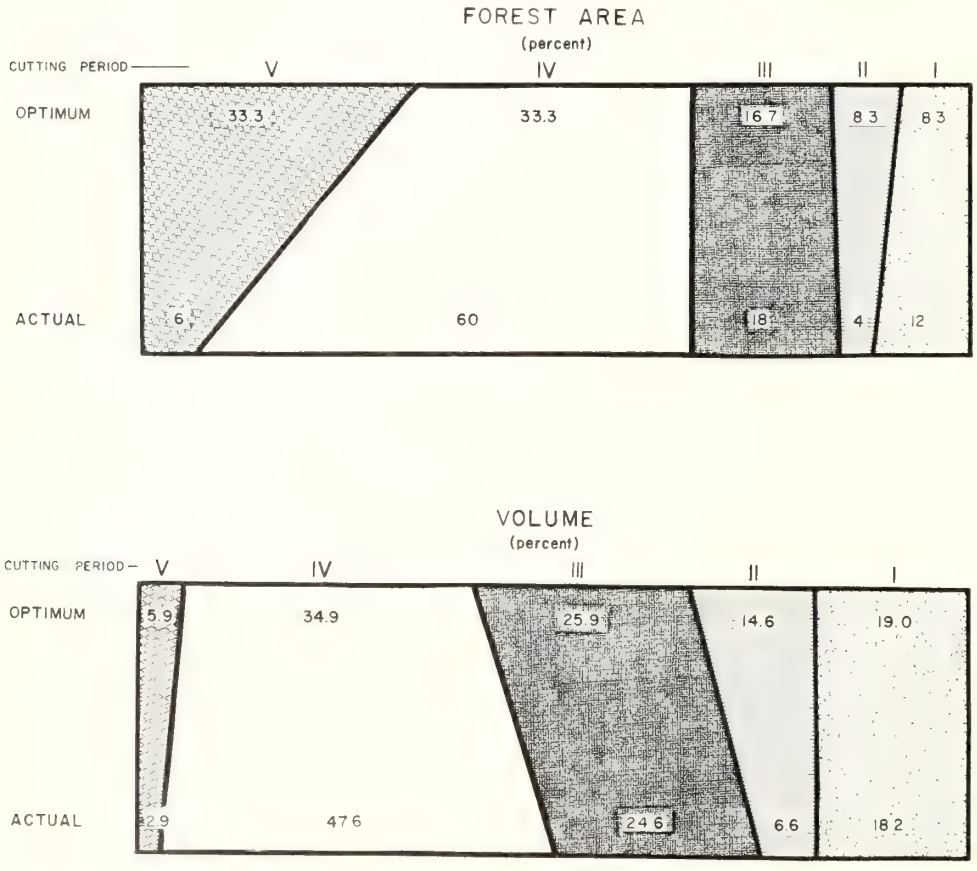

FIGURE 10. — Comparison between optimum and actual area and volume distribution, jack pine type, Thunder Bay River State Forest. Figures do not add to precisely 100 percent because of rounding.

until 1928 when 13,027 acres were established. During the next 14 years 211,954 acres, or 63 percent of the plantation area established to date, were planted. Since 1941, however, only 87,811 acres, or 26 percent of the total, have been established. All told, 341,393 acres of trees were planted between 1904 and 1960, but this includes some areas that were replanted. Actually the net area restocked by planting totaled 295,087 acres.

Planting rates have dropped gradually during the past 10 years. In 1955 the Conservation Commission approved a goal of 20,000 acres per year. At this time it was estimated that 250,000 acres needed to be planted. In 1960 the Commission decided to reduce the annual planting rate from 20,000 to 10,000 acres, and the reforestation goal to 80,000 acres. Since 1955 about 80,000 acres had been planted, and another 90,000 acres removed from the area to be planted by agreement between the Forestry and Game Divisions. Nearly all of the 90,000 acres were in areas being withheld because of game habitat requirements, but some were removed because natural regeneration had taken place. A further reduction of planting to an annual goal of approximately 5,000 acres will become effective in 1964.

Timber Stand Improvement Activity Stepped Up

Prior to 1962 timber stand improvement cutting was done only at the time of commercial harvesting. Funds were not available for cutting in nonoperable stands. As the planting program is reduced, funds from State Forest timber sales will be used for other forest management practices including timber stand improvement. Table 13 shows that about 130,000 acres are in need of timber stand improvement between 1962 and 1972. Not all of the areas scheduled for treatment will yield a commercial harvest within the 10-year period. Many poorly formed and low-quality trees should be removed if growth rates of the desirable growing stock are to be increased.

It is further estimated that an additional 80,000 acres will need treatment in 1972-82. After 1982 relatively little area should need timber stand improvement work aside from that required during normal harvesting periods.

Protection Programs Guard Against Fire, Insects, and Diseases

Until protection against fire was assured, State Forest management was in jeopardy. Currently, the area being burned over annually is well below

TABLE 13. — *State Forest areas in need of timber stand improvement for the period 1962-72.*
(In acres)

Type and region	Stand size and stocking				Total
	Small sawtimber		Poletimber		
	Good	Medium	Good	Medium	
Northern hardwoods					
Region I	2,017	15,826	12,986	35,435	66,264
Region II	-	2,204	19,278	31,615	53,097
Hemlock					
Region I	320	5,521	196	1,202	7,239
Region II	-	-	488	-	488
Pine					
Region I	669	1,473	-	291	2,433
Region II	-	33	82	479	594
Total	3,006	25,057	33,030	69,022	130,115

0.1 percent of the total area protected — a level well below the goal of most forest fire control agencies.

In addition to the fire protection program, the Michigan Conservation Department sponsors a Statewide forest pest detection and control system. This program, which was the first of its kind in the Nation, was organized in 1950. The objectives of the program are, (1) To detect the presence of forest insects and diseases, and to apprehend outbreaks by systematically and annually collecting records of occurrence and damage; (2) to facilitate and organize direct control in case of emergency; and (3) to provide a basis for protective measures by indirect means (Mich. Dept. Conserv. 1961).

The Pest Detection and Control Program is carried out in cooperation with various other public agencies. However, actual fieldwork is conducted by the field personnel of the Forestry Division, which handles State and private lands, and the U.S. Forest Service, which handles National Forest lands. It should be noted that legislative approval has been obtained to use reforestation funds for forest protection purposes, primarily to facilitate insect and disease control.

Multiple-Use Concept Guides Management of State Forests

So far the discussion of the management of Michigan's State Forests has emphasized timber production. But timber production, game management, and recreation are given equal emphasis in deciding how the State Forests are to be managed.

A wide variety of recreational facilities has been developed on State Forest land as a result of the Conservation Department's multiple-use policy. They include campgrounds, public fishing sites, swimming beaches, scenic drives, nature trails, natural areas, game areas, deer yards, and openings managed for wildlife habitat.

Greatly expanded use of the State Forests' recreational facilities is anticipated. To meet the need, the campground system will be enlarged considerably within the next few years (fig. 11). There are now 100 campgrounds. Plans call for 100 more to be developed in the immediate future. There are now 13 foot-trails and 6 scenic forest drives. It is hoped that in the near future each of the 23 State Forests will have several designated foot-trails and at least one scenic drive.

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FIGURE 11. — Camping in Michigan. Proximity to several large, rapidly expanding metropolitan areas has provided the impetus for enlarging State Forest campground facilities.

To better coordinate the Department's multiple-use policy, the Forestry Division in cooperation with the other divisions is now preparing a composite multiple-use map which incorporates a *primary forest use classification* system. Previously no single document delineated the present and potential uses of all State-owned forest lands.

The primary forest-use classification system recognizes 10 different categories:

1. — *Timber* — game — recreation
2. — *Game* — timber — recreation — deer yards
3. — *Recreation* — game — timber
4. — General game
5. — Natural areas
6. — Special
7. — State Parks
8. — Public fishing sites
9. — Grazing
10. — Minerals

The first three categories are combination uses; one use (that listed first and italicized) is recognized as having first priority, but with management tailored so as not to preclude the development of certain zones within such areas for the secondary uses. The remaining seven categories are single-use areas.

The primary-use classification map is not intended to be a field operating plan. Field maps and plans for each of the individual forests serve this purpose. Rather, this map (fig. 12) is of a general nature designed to show the public that

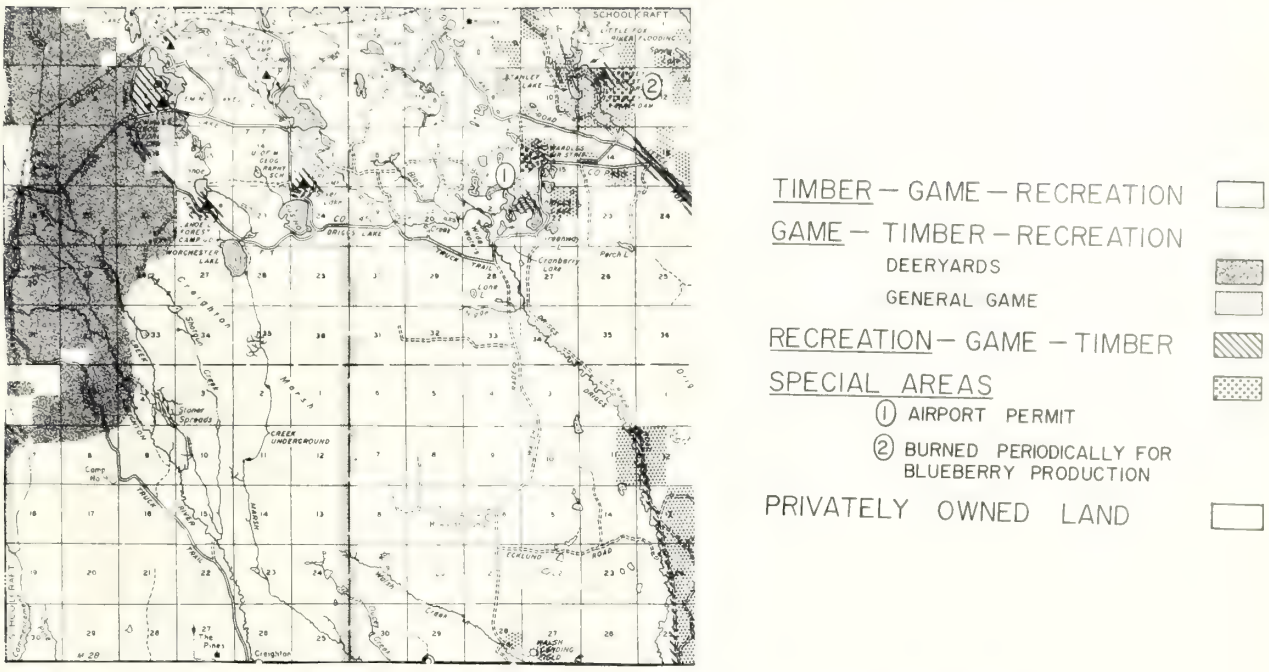

FIGURE 12. — Map depicts multiple-use management on a State Forest.

such a planned program exists and to serve as a guide in protecting certain high-value areas from encroachment by other uses.

National Forests

The National Forest system in Michigan dates back to 1909 when the Marquette and Huron National Forests were established through Presidential power to designate forest reserves from the public domain. Since little public domain remained east of the Plains States — only portions of National Forests in Alabama, Arkansas, Minnesota, and Florida, as well as Michigan were established from public domain lands — the acreage of National Forests in Michigan was naturally quite limited. The Weeks Law of 1911 provided for expansion of the National Forests by authorizing the purchase of land at the headwaters of navigable streams. Still later, in 1924, the Clarke-McNary Act extended the Federal land purchase policy to include lands necessary for the production of timber. But like the State Forest system, the Michigan National Forests did not begin to approach their present size until the 1930's when tax delinquency became common.

During the 10-year period 1930-40, the area grew from 94,000 to 1,965,300 acres. Since that time it has increased about one-third to where, in 1962, Michigan has 2,558,327 acres of National Forest

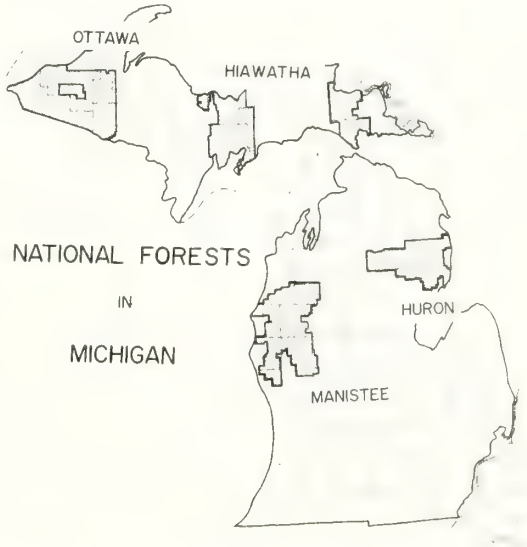

FIGURE 13. — Location of National Forests in Michigan.

lands in four Forests: the Huron, Manistee, Ottawa, and Hiawatha (fig. 13).

Gross area within the boundaries is 4,713,326 acres, but only 54 percent is federally owned. Two-thirds of the National Forest land is in the Upper Peninsula. Most of the area (63 percent) was tax-reverted lands which were purchased directly from the counties. Exchanges with other public agencies accounts for an additional 34 percent, much of which was probably tax-reverted also.

Timber Product Output from National Forests Is Increasing

The output of timber products from Michigan National Forests has been nearly the same as that from State Forest lands, although cutting activity on National Forests predates that on State land by about 10 years (fig. 14). Like the lands that the State "inherited," much of the cutover and burned-over land that comprised the National Forests could not support a commercial cut when acquired by the Federal government. As the acreage of the stands increased and the stands matured, the volume of timber products harvested from the National forests increased. In 1933 the total cut was 931,000 board feet, but by 1961 it had increased to 149.5 million board feet. Total receipts increased a thousand fold during this period, from $1,166 in 1933 to $1,009,364 in 1961.

Again, like the State Forests, the cut from Michigan's National Forests is mostly pulpwood. In 1961, for instance, 81 percent of the volume cut was pulpwood, while saw log products accounted for 10 percent; the remaining 9 percent was posts, poles, piling, and miscellaneous products. The output of pulpwood as a proportion of the total has remained fairly constant during the 1950-62 period. Sawtimber production has dropped and the output of miscellaneous products has increased. As the

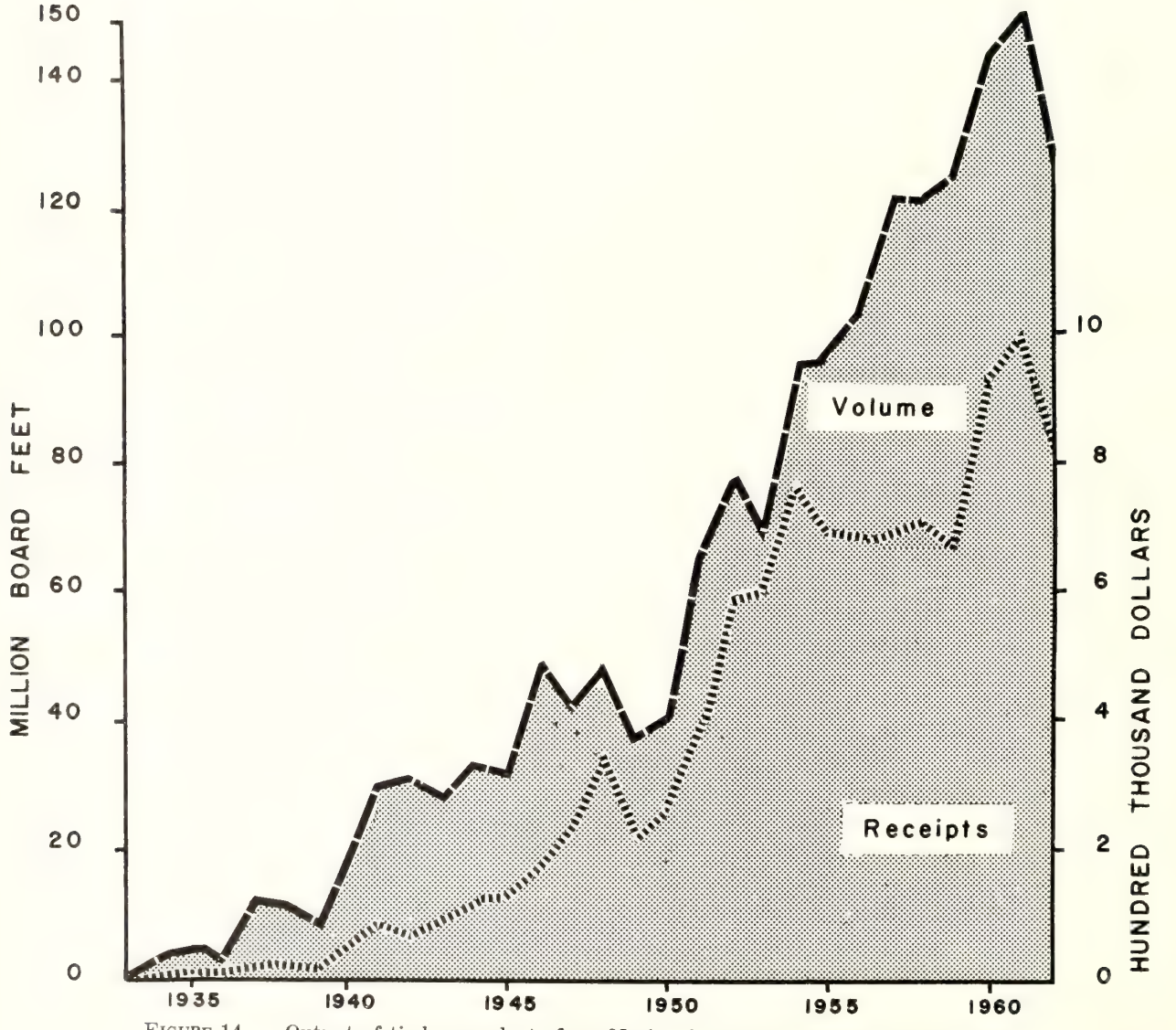

FIGURE 14. — Output of timber products from National Forests in Michigan, 1932-1962.

second-growth stands mature, however, we shall probably see more sawtimber harvested.

During the 1961 fiscal year 658 timber sales were made. These were classified by size as follows:

Size of sale	*Number of sales (percent)*
$300 and under	55.6
$301 - $2,000	30.4
$2,001 - 2,000 MBM	12.5
2,001 MBM - 5,000 MBM	1.5

The majority of sales, 55.6 percent, were for $300 or less. Only 10 sales involved more than 2,000 MBM but these accounted for 20 percent of the timber volume sold.

In addition to the timber sales there were 77 sales of Christmas trees, boughs, etc., with a value of $5,905.

Allowable Cut Still Exceeds Actual Cut

The allowable cut on the Michigan National Forests, like that of the State Forest system, represents the volume of timber that can be removed over a period of years while maintaining or building toward a desirable level of growing stock. The allowable cut, therfore, is a goal as well as a limitation. Allowable cut for a particular type depends upon the operable area of this type as well as its volume, since control is based on area, with volume as a check. The determination of the allowable cut is made from inventory data collected at 10-year intervals.

The flow of timber products varies by forest type. Some types exhibit fairly uniform areas by age classes and support a relatively even flow of material. However, there is a preponderance of young stands, so the allowable cut is much less than total sustained yield capacity. Under continued protection and management these stands will eventually produce the large volume of wood of which they are capable.

In 1962 the allowable cut from Michigan's National Forests exceeded the actual cut by 33.9 million board feet as shown below.

National Forest	*Allowable cut (million bd. ft.)*	*Actual cut (million bd. ft.)*
Hiawatha	56.8	29.5
Lower Michigan[1]	59.1	50.0
Ottawa	42.9	45.4
Total	158.8	124.9

[1] *Includes the Huron and Manistee National Forests.*

Looking at the individual forests, however, one sees that the Ottawa actually exceeded the allowable cut, while the Lower Michigan Forests came fairly close to meeting their goal — undercutting it by only 9.1 million board feet. It is on the Hiawatha where the significant disparity between allowable and actual cut exists. Here, in recent years, market conditions — particularly the lack of demand for aspen and dense hardwood species — have prevented full utilization of the allowable cut.

Present Planting Program Should be Accelerated

As of July 1, 1962, 444,105 acres of forest plantations had been successfully established on National Forest land in Michigan. Of this total, 329,224 acres or 74 percent were established between 1933 and 1942.

Tree planting was discontinued during World War II, and the acreage of successful plantations dropped because of losses from fire, insects, and the lack of maintenance. However, 10,343 acres were planted in 1947 and for the next 15 years an average of 7,500 acres were established annually.

If the planting goals of the National Forests in Michigan are to be met, the present planting programs will have to be accelerated. It is estimated that about 231,000 acres are still in need of planting.

Timber Stand Improvement Largely Sale Area Betterment Work

A large share of timber stand improvement is done as "sale area betterment" work, authorized by Knutsen-Vandenberg (KV) funds. The Knutsen-Vandenberg Act of June 9, 1930, requires that purchasers of National Forest timber make deposits of money in addition to the payment for the timber to cover the cost of, among other things, cutting, destroying, or otherwise removing undesirable trees or other growth. This Act also authorizes payments for regenerating stands and weeding, thinning, and pruning the ensuing young growth (fig. 15).

Through the 1962 fiscal year, 96,044 acres of forest land had been treated in the K-V sale area betterment program. Regular funds that may be used to complete high priority sale area betterment work are also available for stand improvement.

Forest Protection Activity Complements State Forest Programs

Forest fire, disease, and insect detection and control on the National Forests are much the same

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FIGURE 15. — Scaling pulpwood harvested in thinning a young pine plantation. Thinning will become more common in Michigan's National Forests as the large acreage of pine planted during the 1930's reaches merchantable size.

as on the State Forests and are coordinated for efficiency. The risk of forest fire is becoming greater each year with more people using the forests and young coniferous stands maturing. Intensive prevention, detection, and suppression activities are necessary.

Success in reducing the incidence of forest fires on Michigan National Forests despite increased use is shown in the tabulation below:

Year	*Number of fires*	*Acres burned*
1952	233	1,073
1953	199	1,342
1954	158	341
1955	111	382
1956	77	143
1957	140	1,753
1958	165	764
1959	101	321
1960	75	432
1961	185	865

White pine blister rust has required extensive control. Efforts date back to 1932 when Civilian Conservation Corps and National Industrial Recovery Act labor was used to remove the rust's alternate host, ribes, from the proximity of white pine stands. Since this beginning, an average of approximately 5,000 acres of the white pine type have been treated annually.

To date about 80 percent of the 77,600 acres of the white pine type has been placed on a maintenance status. That is to say, ribes have been removed from the area to the extent that only periodic checks are necessary. Insect control measures have been carried out on 16,500 acres during the last 6 years.

Recreational Use Increasing Sharply

The Forest Service has for many years provided public facilities for camping, picnicking, swimming, boating, and hiking. Current trends in the number of recreational visits to Michigan's National Forests reflect a sharp increase in demand. Between 1950 and 1961, for instance, the number of visits increased five times (fig. 16).

Presently 185 recreational sites are maintained on the Michigan National Forests. As shown in the tabulation below, camping sites, picnic grounds, boating sites, and recreational residence areas account for most of these facilities:

Kind of site	*Number of sites*
Campgrounds	52
Picnic grounds	33
Boating sites	31
Recreation residence sites	29
Swimming sites	16
Other recreation sites	24
Total	185

In addition, the Forest Service also provides visitor information services, nature trails, and self-guided tours showing multiple use of a managed forest. Long-range plans call for additional facilities. It is estimated that the number of campground visitors in 1976 will be more than eight times the number in 1958. The use of picnic sites and winter sports areas will at least triple during this same period.

Multiple Use Policy Dictates Use of Michigan's National Forests

The Multiple Use Sustained Yield Act of 1960 was formal recognition by the Congress of the Forest Service policy of managing all of the basic resources found on the National Forests: outdoor recreation, range, timber, watershed, and wildlife. Each ranger district is zoned for multiple use management (fig. 17). It is impossible, of course, to provide for every use on each acre but over the district as a whole many uses can be made available providing the resources are there (fig. 18).

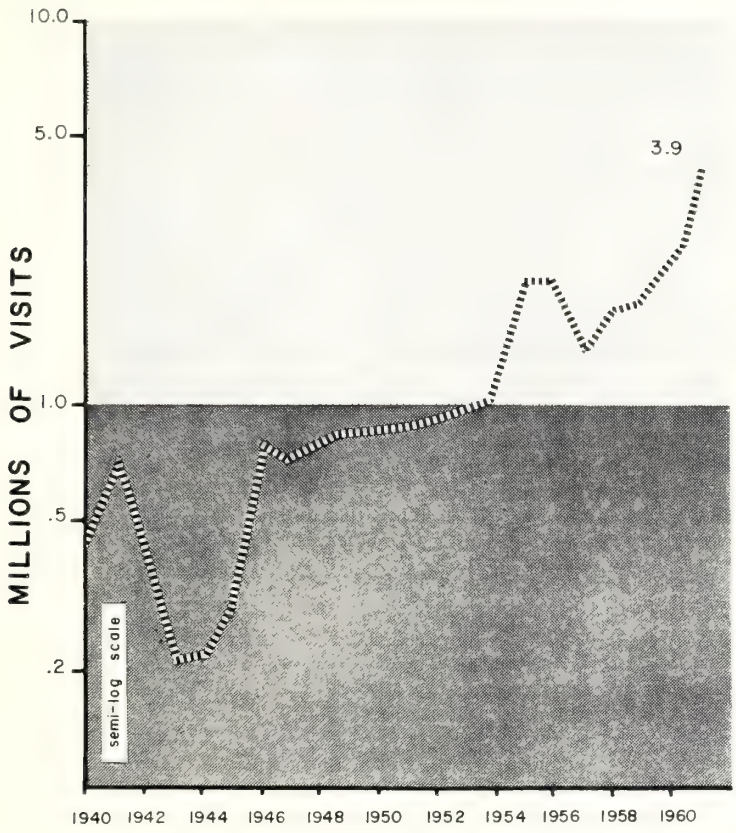

FIGURE 16. — Michigan National Forest recreation visits, 1940-1961.

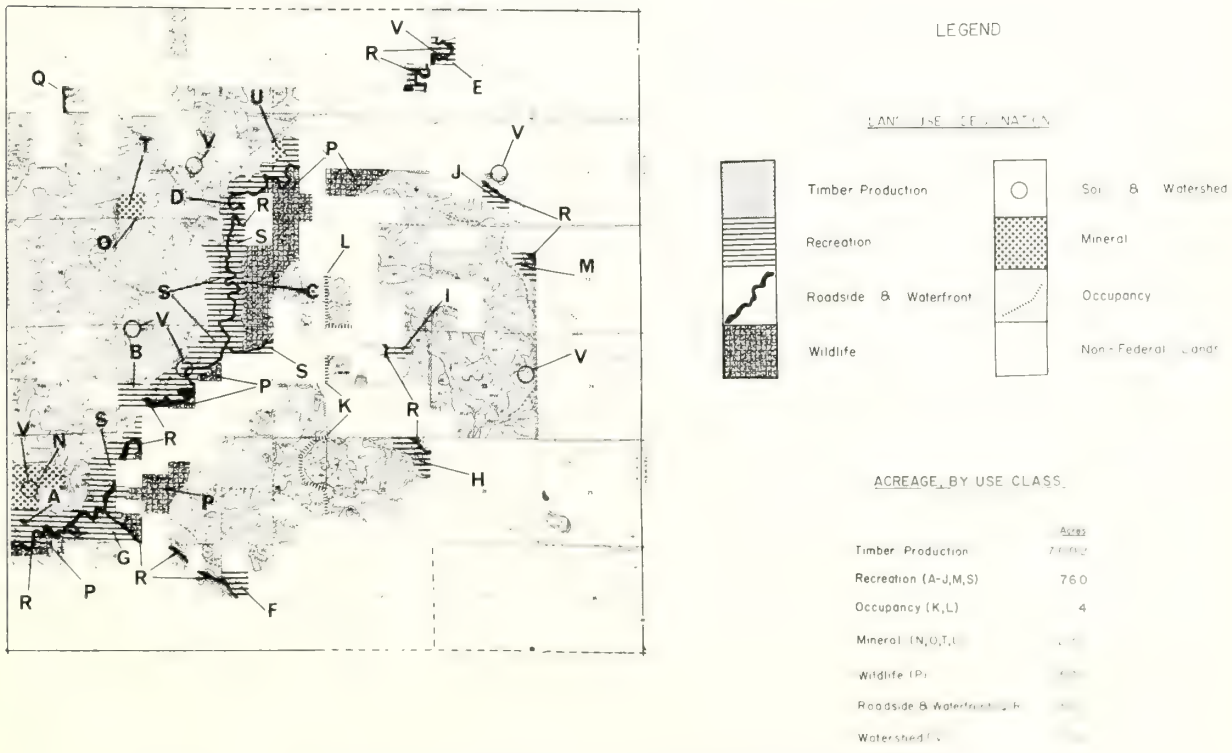

FIGURE 17. — Example of multiple-use management on Michigan's National Forests.

DISCUSSION AND CONCLUSIONS

That the various classes of forest owners in Michigan manage their timbered holdings in different manners is definitely shown. At one extreme are the woodland owners who generally, at best, can be described as "passive producers" of timber products — their forests grow in spite of their neglect or misdirected efforts — while at the other end of the scale are the public forest-land ownerships and several of the large private holdings. The management of public forests does not exactly represent the epitome of intensive forestry, because the level of financing precludes the adoption of many practices, but the State and National Forests as a whole are more intensively managed than any other major grouping of ownerships in the State. Although several of the large forest-land ownerships are being managed at a level at least commensurate with that of Michigan's publicly owned lands, some are not.

The difference in the kind and amount of forest management implemented by the various classes of owners over the years should effect changes of timber output from the different ownership groups. Although data limitations preclude an exhaustive demonstration, it can be shown that investments in management of Michigan's public forest lands are beginning to bear fruit.[6]

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FIGURE 18. — Multiple-use management of Michigan's National Forests assumes varied forms. For instance, the above sign explains how 4,010 acres of forest land is being managed to preserve the nesting habitat of the Kirtland's Warbler.

Timber Cut Decreased Between 1950 and 1960

The total cut of timber products from Michigan's forests decreased somewhat between 1950 and 1960 (fig. 19). This trend is opposite to the upward trends of timber volume and growth but, considering the changes in the market structure for various wood products during the period, such movements are to be expected. The demand for and the supply of hardwood lumber changed considerably because much of the old-growth timber had been liquidated. This is reflected in the change in composition of the timber cut during this period. The cut from sawtimber growing stock for other than pulpwood dropped by 50 percent to a level below that of the total cut of pulpwood products,[7] whereas the cut of pulpwood increased by nearly 25 percent. This increased demand for pulpwood, however, did not compensate for the drop in the demand for lumber.

A look at the contribution to the cut of raw wood products by the various classes of owners brings out some interesting trends. For instance, the cut from privately owned sawtimber growing stock for non-pulpwood products decreased from an estimated 129 million cubic feet in 1950 to 64 million cubic feet in 1960; the cut from public forest lands during this period increased nearly five times (fig. 20). However, the sawtimber cut from public lands still represents only a small proportion of the total cut of sawtimber from all ownerships.

The trends in the cut from poletimber and the pulpwood cut from sawtimber growing stock bring out the fact that not only did the cut from public

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[6] *Trend data on timber cut in Michigan are available for three classes of owners: State Forests, National Forests, and all private owners. Separate estimates for the small private and large private classes are not available.*

[7] *This and ensuing data regarding cut from Michigan's growing stock during the 1950-1960 period are based upon field enumeration and bookkeeping adjustments.*

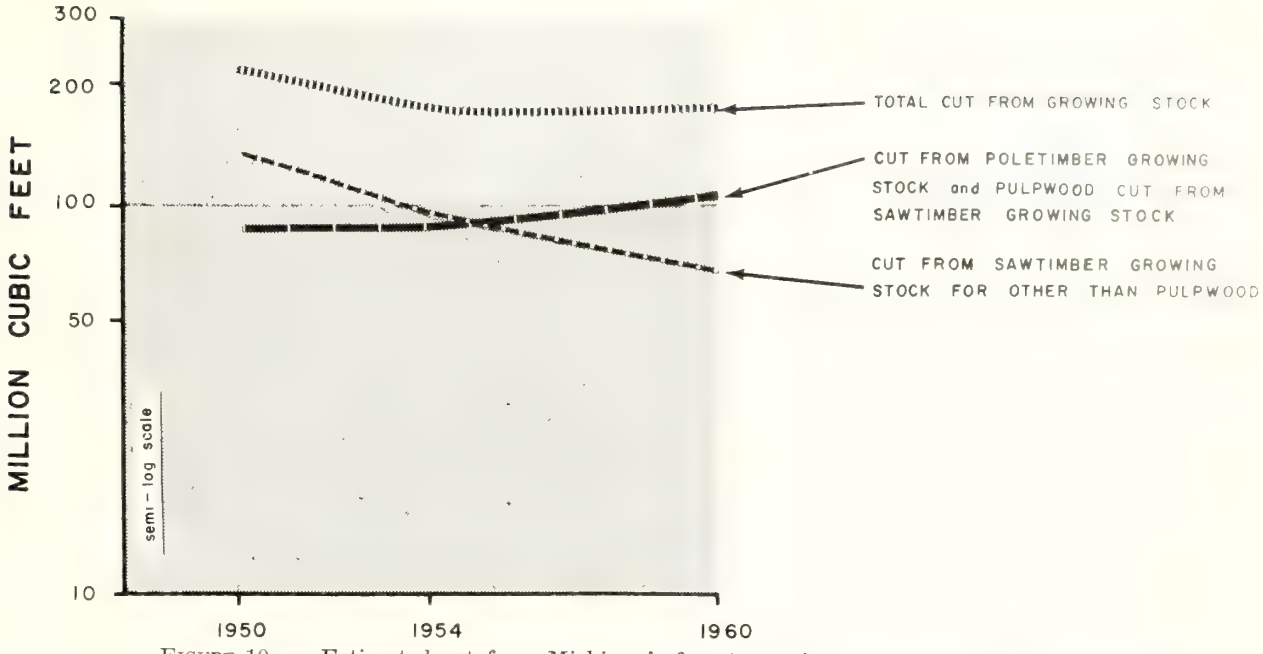

FIGURE 19. — Estimated cut from Michigan's forest growing stock — all products, all owners, 1950, 1954, 1960.

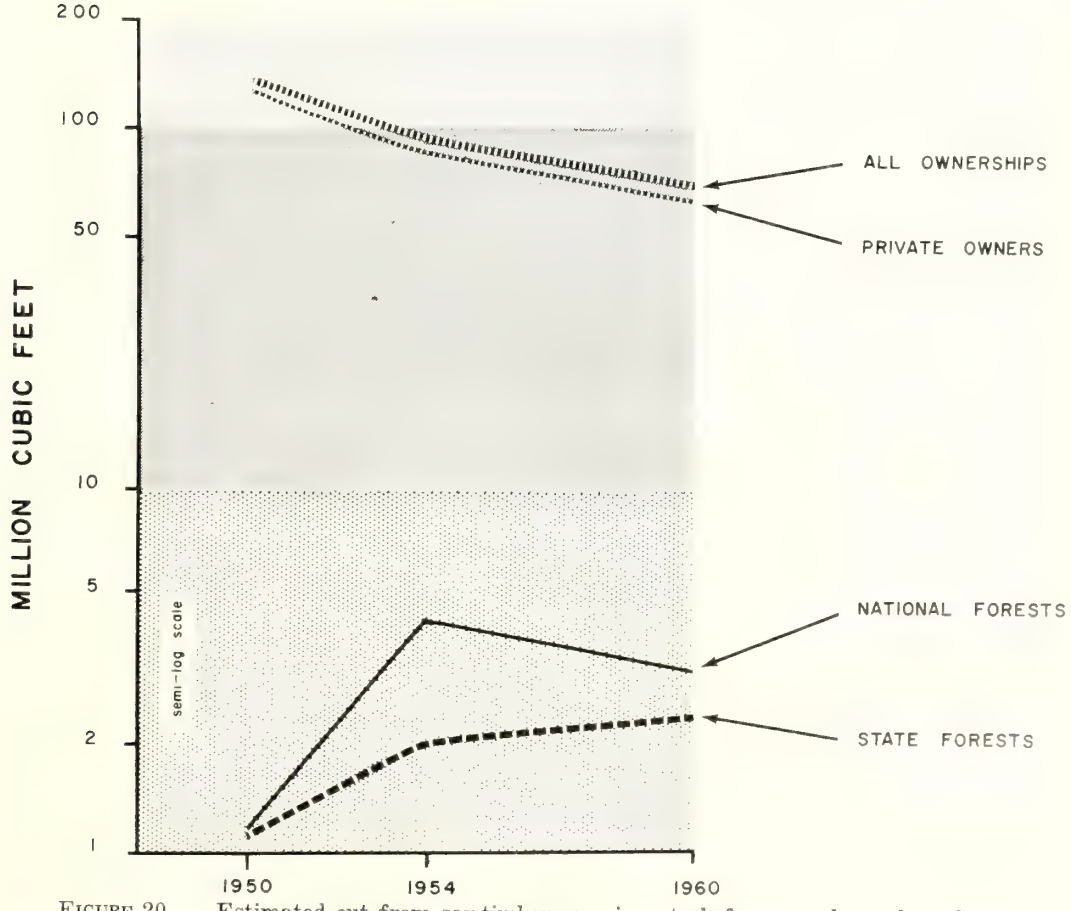

FIGURE 20. — Estimated cut from sawtimber growing stock for nonpulpwood products, by ownership, 1950, 1954, 1960.

lands more than double between 1950 and 1960 but also the cut from State and National Forests combined is beginning to make up a significant as well as an increasing share of Michigan's cut of roundwood products (fig. 21). Private owners on the other hand have increased their cut in recent years, but not enough to regain their 1950 level of output and share of the total market.[8]

[8] *It is not possible to separate the large ownership cut from that coming from small ownerships. However, the contribution of roundwood products from the large ownerships probably increased during the 10-year period.*

Better Management and More Aggressive Timber Marketing Account for Public Forests' Increasing Share of Output

Now the question arises, "Why have the public forests been able to sell increasing amounts of sawtimber in the face of a declining market?" Likewise, "Why have the public lands been able to increase their output of roundwood products while private owners, in 1960, were not back to their 1950 level of roundwood production?"

Certainly one of the answers is more and better management. The quality and quantity of wood

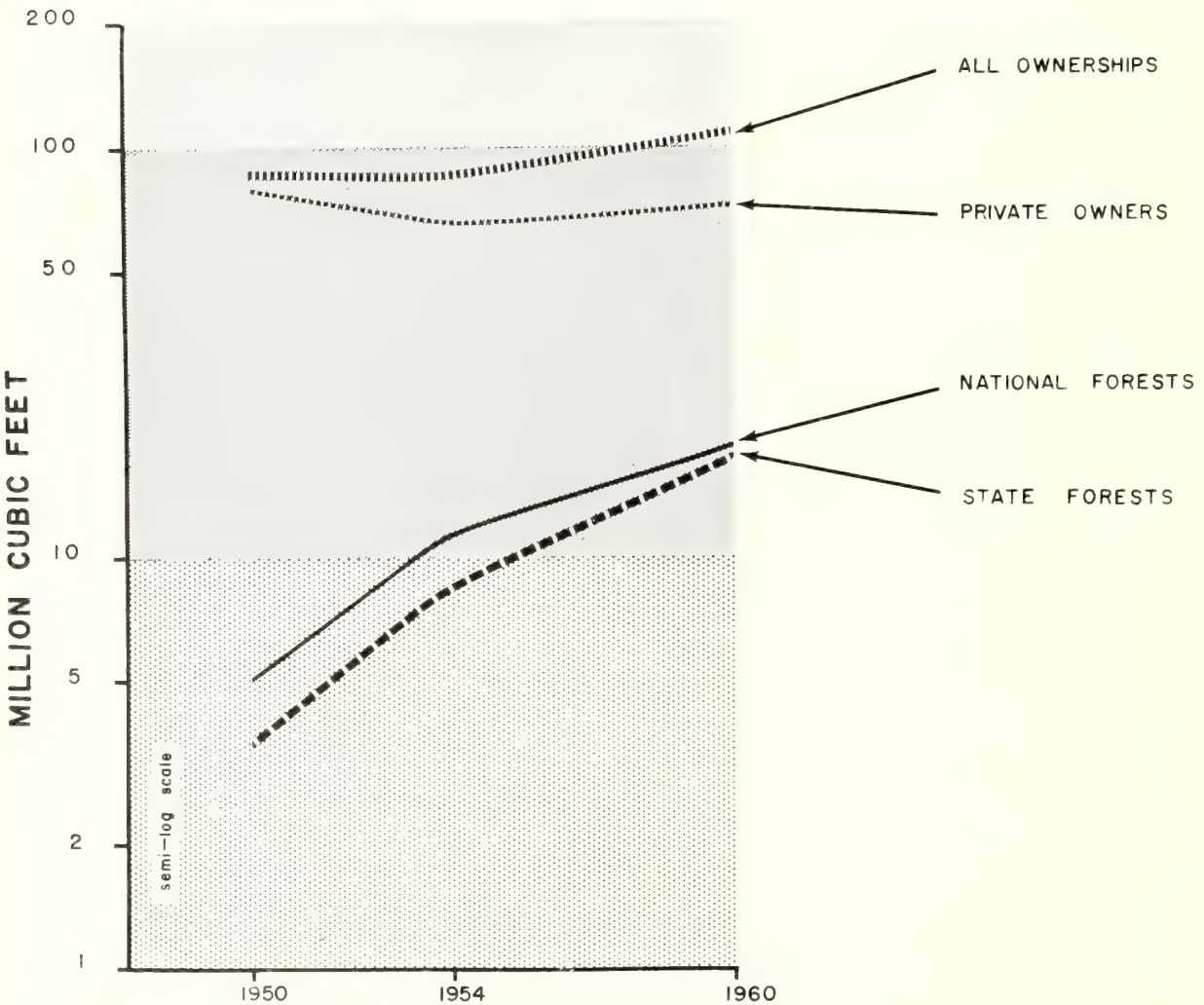

FIGURE 21. — Estimated cut from poletimber growing stock and pulpwood cut from sawtimber growing stock, by owners, 1950, 1954, 1960.

products have improved more on public lands than on private lands because timber harvesting from public forests is geared to a computed allowable cut designed to increase productivity.[9] Timber harvesting on the majority of small private holdings meanwhile has not been such as would enhance quantity or quality of output.

Still another reason for the increased output of timber products from public lands versus the decline from the private sector — and perhaps just as important a reason — is that public forest land managers "merchandise" their wood products whereas the private owner usually takes a passive interest in the prospects of selling wood. Public foresters are continually striving to promote the sale of the allowable cut on public lands, whereas the private owner usually waits until a buyer approaches him before considering a sale.

[9] *One might attribute the ability of public lands to increase their output mainly to the reduction of forest fires to a low level. But if this were the case private forest lands would also be supporting increased timber output because fire history of both private and public land has been essentially the same.*

Public and Large Private Forest Lands Will Increase Their Share of Timber Output

The output of all timber products from Michigan's public forests quadrupled between 1950 and 1960, while the cut from private lands dropped by 32 percent (fig. 22). Although data are not available, the large private ownerships, like the public lands, probably increased their output of timber products during the 1950-60 period, since, as was pointed out earlier, the productivity of many large private ownerships was rated higher than that of public lands.

As a result of concerted efforts to increase output, public forests and large private ownerships will undoubtedly continue to increase their share of the total output for some time. But there is a limit to the contribution that they can make.

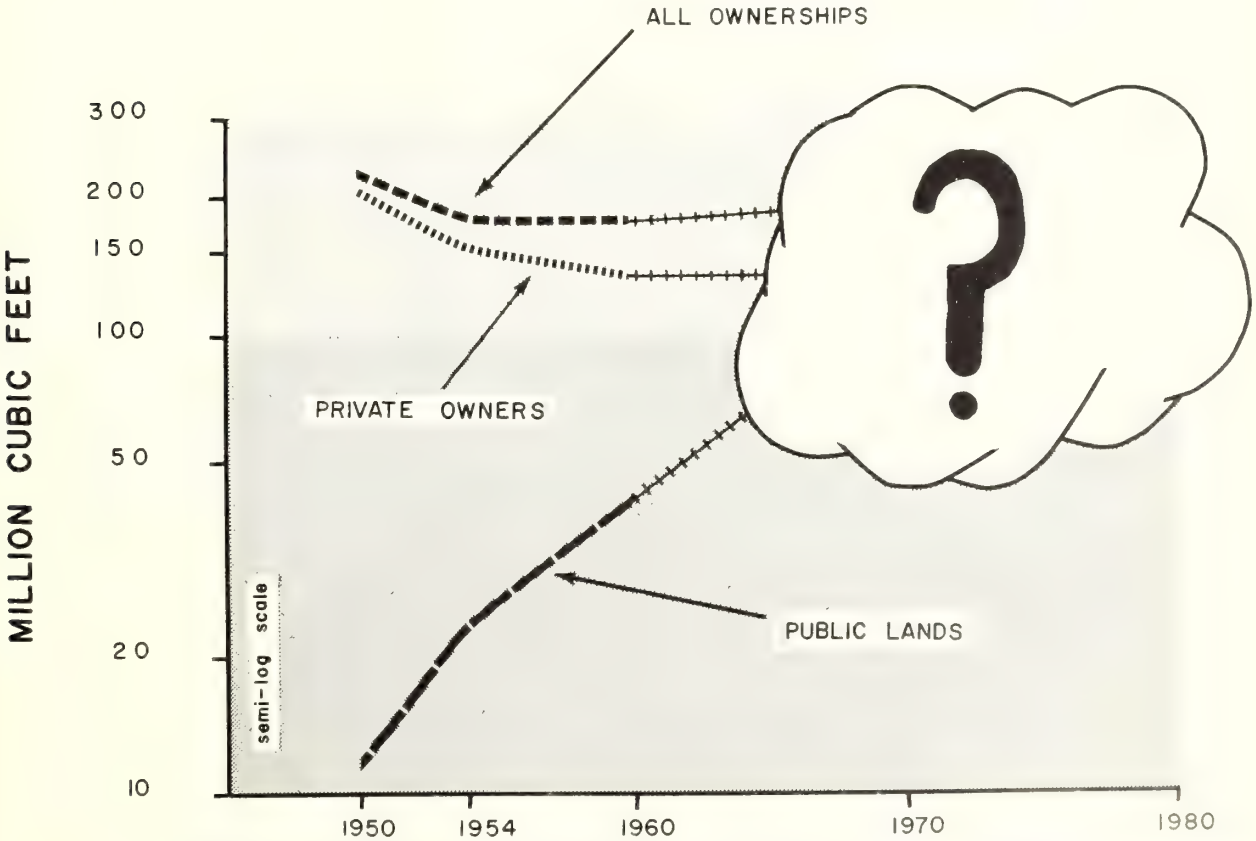

FIGURE 22. — Estimated cut from growing stock, all products and all owners, Michigan, 1950, 1954, 1960. Projected trend lines suggest that total cut from public lands will equal that from private forests by 1980.

It is apparent from figure 22 that the public forests' contribution to timber production has caused the total cut from all forest land to level off and show signs of increasing. But a projection of current trends to 1970 would show only a modest increase in the total output — from 178 million cubic feet in 1960 to 188 million in 1970. Total cut from private land would continue to drop despite a slight increase in private pulpwood production. The drop in saw log production would be greater than the upswing in pulpwood output. However, the cut from public lands would increase enough to more than offset the decrease in lumber output from private lands, to a point where public forests would be contributing more than their share, proportionate to area, of the total timber cut — 37 percent of the cut from 33 percent of the forest area. Assuming that current trends persist, the output from public forests would equal that of private owners sometime between 1975 and 1980.

The projected trend in cut from public lands would seem to be fairly realistic. Although public forests are presently selling less than their allowable cut, the doubling of the present output during the next decade and a half — which would occur if present trends continue — probably approximates the maximum under present standards of utilization. In addition, a doubling of the output would have to be accompanied by sizable increases in the number of public foresters to handle the added timber sale administration. All in all, it is the owners of small forest holdings who must be encouraged to improve their productivity if Michigan is to appreciably increase its timber output in the long run.

As just mentioned, extension of current trends in timber cut would find the private and public ownerships producing at the same level by 1980. However, Forest Survey estimates of future growth (Findell et al. 1960, p. 15) suggest that the *biological* potential of private forest lands would actually support more than twice as great a cut as the extension of current trends would indicate. Actually, instead of current trends persisting, we would expect the cut from privately owned forest land to increase more or less "spontaneously" as the second-growth stands mature, assuming, of course, that the owner desires to sell timber products. But it is doubtful that the contribution of the small privately owned forests will approach their potential unless steps are taken to encourage more of the owners to practice forestry.

Equi-Marginal Principle a Guide to Distribution of Inputs

The productivity of Michigan's forest resources could be increased in many ways, but greater benefits can be derived from certain opportunities than others. For instance, physically much could be done to increase the wood-producing potential of the small ownerships because so little has been accomplished in the past. But the mere existence of problems to be solved does not dictate the expenditure of funds and manpower. Conceivably, equipment and labor presently being used to plant trees on public forest land might achieve more in terms of increased timber values if expended on private lands. On the other hand, a reallocation of productive inputs might dictate their use to sponsor timber stand improvement activities elsewhere on public lands and not to plant trees on small private ownerships. Or it could be that some of these funds should be used to promote better forestry practices among a selected portion of small ownerships while the remainder be reallocated to timber stand improvement on public land.

These alternatives are hypothetical, but they demonstrate how decision-makers could approach the problem of maximizing the output of timber products from Michigan's forest lands with the funds available to them. We cannot maximize the returns to inputs as long as opportunities exist to shift inputs from one forestry endeavor to a more economically efficient one. Of course, there are political and institutional factors which inhibit the application of the equi-marginal principle. Funds are often earmarked by legislative bodies for particular practices, and funds are appropriated by both State and Federal units of government; but where possible, land, labor, and capital inputs could be allocated so that the marginal units are deriving at least as great benefits as could be obtained from alternative uses.

Certain Ownership Characteristics and Land Use Patterns Affect Timber Products Supply

A comparison of the allowable cut and actual cut from Michigan's forests seemingly reveals a timber surplus. In 1955, for instance, the total cut from all species and all owners was only 64 percent of the allowable cut. Although these estimates are

not current, the discrepancy probably still exists — and is perhaps even greater since growth trends have been upward while production has leveled off in recent years.

The important question is, "How much of this disparity between allowable and actual cut goes unharvested simply because of a lack of markets?" In other words, is it realistic to assume that all of this volume differential would be marketed if the demand for timber products increased? As far as many of the large private ownerships and the public forests are concerned the answer may well be in the affirmative. However, when one considers inhibiting factors peculiar to the small ownership group, their potential to produce timber may not be much greater than current levels. For one thing, although they may not now be harvesting their allowable cut, traditionally they have overcut certain species and age classes, and so probably the difference between actual and allowable cut from small forest ownerships is less than from other classes of owners. Just as important perhaps, certain ownership characteristics and land use patterns inhibit, if not preclude, the marketing of some of their allowable cut (fig. 23).

The majority of small woodland ownerships are held for reasons other than timber production. This factor serves to restrain the flow of timber products. In fact, objectives of ownership are sometimes incompatible with timber harvesting. For instance, the recreation-motivated owner usually considers the psychic returns of land ownership ample justification for retaining his forest land; income from timber has little appeal. If this class of owner increases, the supply of timber products will be reduced unless owners can be shown that timber production is compatible with and in fact often enhances certain recreational values.

Another ownership characteristic that has a bearing on the trend in Michigan's timber output is absentee ownership (this type of owner, of course, is not mutually exclusive of the recreationist owner). Absentee owners are less apt to market timber products than resident owners. Unless the absentee owner contacts a buyer, it is difficult for the buyer and seller to come to terms. A timber buyer in the Upper Peninsula is not going to spend much time getting in touch with the owner of a 40-acre stand of aspen if the owner lives, say, in Detroit. On the other hand, the small return involved might not be enough to interest the owner in negotiating, in absentia, for the sale of his timber even if the buyer does make a contact.

Although absentee ownership could reduce the economic supply of timber in Michigan, there's another aspect of absenteeism that could ameliorate the timber drain situation. True, the absentee owners are physically separated from the timber market, but likewise they are usually less dependent upon their woodlots as a source of income. Over the long run, therefore, these two factors — distance and income source — could lead to less premature cutting and thereby improve the quality and quantity of timber growing stock. Conceivably, the conflicting aspects of absentee ownership could counteract one another.

Fragmentation of privately owned forest properties into smaller and smaller parcels is another feature of the Michigan timber resources that could also restrict the flow of timber products. We know, for instance, that in the Upper Peninsula there are now approximately 1 million more acres of forest land owned by the small ownership class than in 1935. A recent study in the north half of the Lower Peninsula shows that fragmentation has been occurring in that area.[10] Should the average size of privately owned forest property decrease appreciably, the incentive, from the standpoint of both the buyer and seller, to harvest timber from many properties might be significantly hindered.

Having much the same effect as fragmentation is the factor of urbanization. It has been estimated that, if population growth and economic activity are maintained, the annual rate at which private forest land in southern Michigan will shift to nonforest uses in the next decade will be approximately 1 percent (Schallau, 1962, p. 11). Of course, growing stock harvested or otherwise removed to make way for urban uses will no longer enter into the computation of allowable cut. But as was previously mentioned, urbanization can isolate blocks of growing stock from timber product markets, and then, despite the existence of merchantable timber volume, these stranded pockets of forest land would cease to be effective suppliers of timber products.

It may seem inconsistent to be concerned with factors that inhibit the flow of timber products

[10] *A study of forest land fragmentation or consolidation in the northern half of the Lower Peninsula was conducted by the author during the summer of 1963. The results of this research will appear at a later date.*

from Michigan's forests at a time when timber markets are showing signs of weakness. On the contrary, when one considers the long-run and not just current movements, the discussion is quite appropriate. Building activity is cyclical, and it should only be a matter of time before an upswing will be reflected in the timber market place; this upswing, when coupled with a steadily increasing demand for pulpwood products, points toward increased wood requirements in the future.[11] The demand for wood stemming from building activity may assume different forms in the future than in the past, but there is little reason to suspect that Michigan will have a chronic oversupply of timber in years to come.

Because allowable cut computations do not take the "inhibiting" factors into consideration, the present drain of forest products may be closer to the maximum possible than allowable cut-actual cut comparisons imply. Timber supply response information for Michigan is not available, and

[11] *In recent years approximately 30 percent of the saw log cut in Michigan has come from softwood growing stock. Much of this material (hemlock in particular) is manufactured for the building industry. Some of the cut from hardwood saw logs is used for flooring, interior trim, and cabinet work, but a large share goes into furniture. But since there is a close correlation between home formation and furniture purchases, even the demand for furniture saw log material is responsive to the building cycle.*

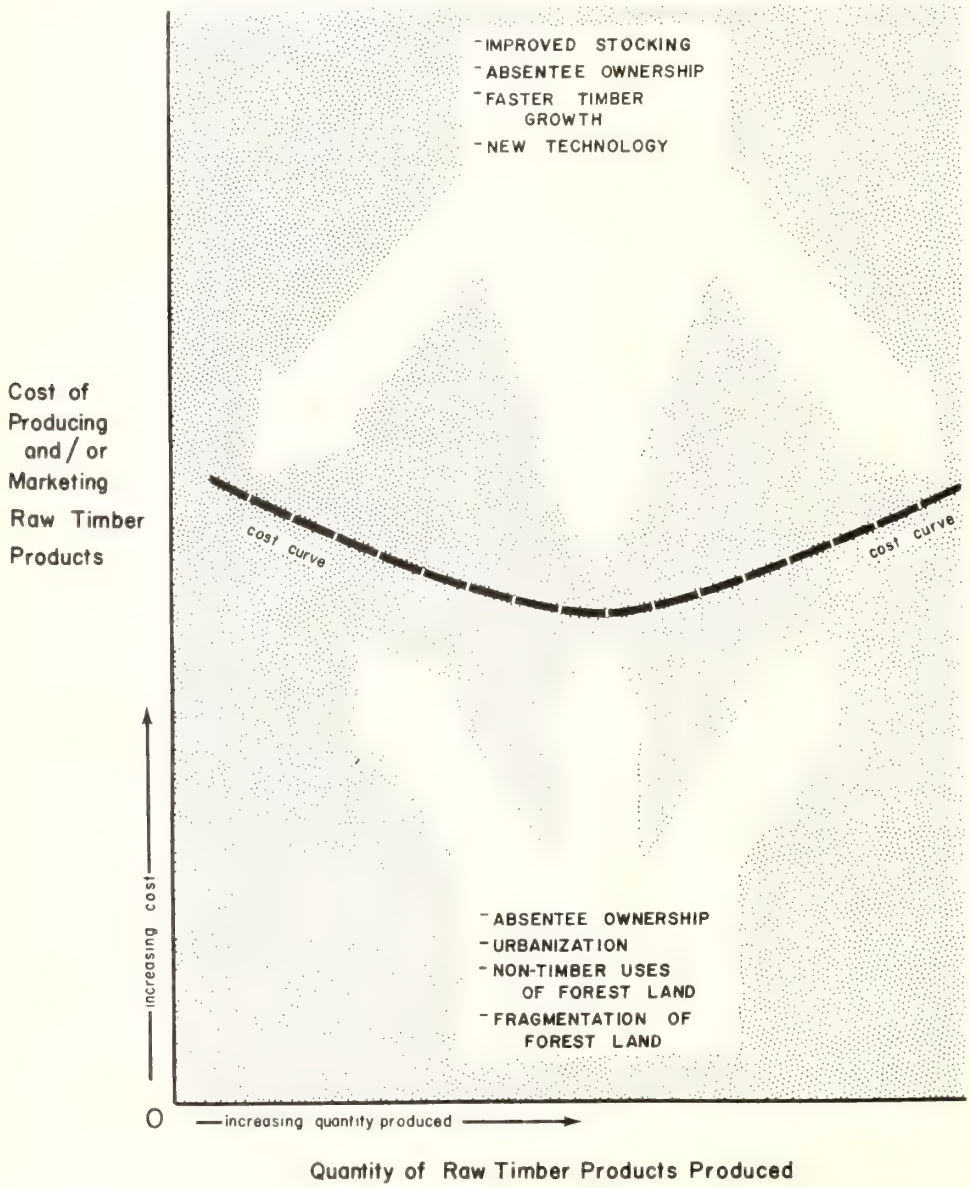

FIGURE 23. — This schematic drawing shows a number of factors and their probable effect on the cost of producing and marketing raw timber products from Michigan's forests. It is hypothetical and is only intended to indicate whether a factor is cost-decreasing or cost-increasing. Note that absentee ownership could conceivably increase as well as decrease production and marketing costs.

without it we can only speculate as to whether timber supplies will be adequate for the future. The existence of increasing volume and growth of timber resources — which Michigan exhibits — is not tantamount to increases in the volume of wood products harvested. Conceivably, certain "supply inhibiting" ownership characteristics and land use changes could negate the effects of increased growing stock volumes. This appears highly improbable for the State as a whole, but it is obvious that future timber product output, although a function of available growing stock volumes, will not vary at a one-to-one ratio with changes in physical timber supplies.

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The Causes of Maple Blight in the Lake States

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CONTENTS

Page

ACKNOWLEDGMENTS i

SUMMARY AND CONCLUSIONS 1

INTRODUCTION 2

DETECTION AND APPRAISAL SURVEYS 3

- Detection Survey 3
- Appraisal Survey 4

DEFOLIATION STUDIES 6

DISEASE STUDIES 9

INSECT STUDIES 11

ECOLOGICAL STUDIES 13

ACKNOWLEDGMENTS

The maple blight studies are an outstanding example of cooperative effort to resolve a crisis situation. Actually, so many individuals and organizations made major contributions that it is hazardous to try to enumerate them. We are attempting to do so and hope that we are not remiss and neglect any major contribution.

First, we wish to give credit to the research scientists and survey personnel whose work provided the results presented in this paper. The Station's detection and appraisal survey was conducted under the direction of Dr. Ralph L. Anderson, who was ably assisted by Dr. David W. French, Department of Plant Pathology, University of Minnesota, and Dr. Gene A. Hesterberg, Forestry Department, Michigan Technological University. The Wisconsin Conservation Department conducted intensive surveys for maple blight and the associated insects. They also collaborated with the Station in appraising the problem. Most of this work, done under the direction of Mr. Don Renlund, was accomplished by Mr. Stanley Banash. In Michigan Mr. Norman Smith of the Michigan Conservation Department collaborated with the Station by providing reports on possible blight areas received from the Department's field personnel and others cooperating in pest detection work.

Research to determine whether any pathogens were responsible for maple blight was conducted by Dr. David R. Houston under the guidance of Drs. A. J. Riker and J. E. Kuntz of the University of Wisconsin, Department of Plant Pathology.

Research on the role of insects in the maple blight problem was conducted by Drs. Ronald L. Giese and Joseph E. Kapler under the guidance of Dr. Daniel M. Benjamin of the University of Wisconsin, Department of Entomology. Dr. Roy D. Shenefelt contributed to the University's efforts by identifying insects.

Research on ecological factors was conducted by Mr. Darroll D. Skilling of the Station's staff, under the general supervision of Mr. R. A. Ralston. Consultation and advice were provided by Mr. F. H. Eyre, retired, a well-known authority on northern hardwood silviculture.

For various reasons, all of the above research studies included defoliation of maple. In addition, Dr. Gene A. Hesterberg of the Michigan Technological University studied the effects of defoliation.

Second, we wish to express appreciation for the financial support that made these studies possible. The Lake States Forest Experiment Station received contributions of $12,000 from the Northern Hardwood and Pine Manufacturers Association, $10,000 from the Maple Flooring Manufacturers Association, and $2,000 from the Birch Club. This $24,000 contributed by industry, plus appropriated funds made available by the Station, were the major sources of financial support used to initiate the studies. The Lake States Station in turn provided the University of Wisconsin with $12,000 to support their work on the problem. The Wisconsin Conservation Department also contributed substantial financial support needed to carry to a conclusion the studies conducted by the University of Wisconsin.

Third, we wish to express appreciation to the several groups that cooperated so effectively in facilitating development of a sound, coordinated program of study. At an action committee meeting in Wausau, Wis., in January 1958, the first steps were taken for organizing a research program. Participating in this meeting with the Forest Service and providing invaluable guidance were representatives of the Northern Hardwood and Pine Manufacturers Association, Connor Lumber and Land Company, Goodman Division of Calumet and Hecla, Inc., Kimberly-Clark Corp., Wisconsin Conservation Department, Michigan Conservation De-

partment, University of Minnesota, University of Wisconsin, University of Michigan, and Michigan Technological University.

A steering committee composed of representatives of the Northern Hardwood and Pine Manufacturers Association, the Maple Flooring Manufacturers Association, the Birch Club, and the Wisconsin Conservation Department provided effective guidance in making the formal cooperative arrangements for the financial support of the project by industry and in determining how these funds should be distributed and expended. Mr. Allan S. Haukom, Secretary-Manager of the Northern Hardwood and Pine Manufacturers Association, during the early period of the studies, and his successor, Mr. William A. McGraw, were particularly helpful to the Station in handling many of the details involved in such cooperation, including arrangements for a number of meetings in Green Bay, Wis., at which progress to date was presented by the research workers.

In conducting the studies, cooperation given by the University of Wisconsin on the insect and disease research was essential. The Goodman Division of Calumet and Hecla, Inc., also provided an essential service in making the maple blight area available to the researchers and in facilitating their use of the area.

SUMMARY AND CONCLUSIONS

In 1957 severe damage and mortality of sugar maple in Florence County, Wis., resulted in a strong cooperative research effort among Federal and State agencies and industry to determine its cause. Detection and appraisal surveys and insect, disease, and ecological studies were made. The following conclusions were drawn:

Much of the alarm about the maple blight problem at the time of its outbreak in Florence County, Wis., was based on the fact that the cause was unknown; hence, the possibility of a virulent pathogen that could cause sustained widespread devastation could not be ruled out. Since no virulent pathogen was discovered, the chances are that any future outbreaks of maple blight will be sporadic and rather localized, although damage in such areas could be severe.

All studies of the problem support the view that insect defoliation is the primary cause of maple blight. This conclusion indicates that sugar maple is much more susceptible to serious injury from a relatively limited period of defoliation than was previously considered to be true for hardwood species. This, the major finding of the maple blight studies, calls for a considerable reorientation in attitude toward defoliation of sugar maple. The studies also indicated that timing of defoliation is very important if serious damage is to occur. The defoliation must be early enough in the season so trees reflush, and it must be late enough so the reflush growth does not harden off at the end of the growing season. July to early August, therefore, is the critical period for maple defoliation.

With reference to the defoliating insects, the most significant finding is that the webworm does the damage but a population of leaf rollers is essential to the development of a webworm epidemic because it lays its eggs only in rolled leaves.

The research studies also showed that other factors contribute to the severity of maple blight damage. Armillaria root rot appears to increase the amount of postdefoliation mortality — mostly the mortality that occurs the second and third years after defoliation. Previously killed trees and stumps apparently provide the food base that seems to be necessary in order for Armillaria to aggressively attack living trees. Below-normal soil moisture levels increase the severity of maple blight symptoms. Hence, defoliation coincidental with a period of drought would result in somewhat greater damage than would occur under other conditions.

Maple blight damage is more severe in understocked stands and in stands composed primarily of sugar maple. Most likely low stocking and higher proportions of sugar maple favor buildup of the defoliating insects; therefore, the effect of these factors on blight development is a reflection of conditions favorable for high insect populations.

Evidence also suggests that fall frosts may be a very important factor. The reason for this is the killing of buds on reflush growth that is not yet hardened off. The timing and severity of fall frosts following defoliation and reflush may therefore seriously affect the severity of maple blight damage.

An important consideration is the action to be taken in future outbreaks of the complex of defoliating insects that lead to development of maple blight. Of the various factors affecting development of maple blight, only two lend themselves to what might be considered indirect control or prevention of outbreaks. These are stocking and stand composition. Efforts to maintain good stocking and, to the extent possible, a mixture of species would help to minimize the possibility of severe outbreaks of the defoliators and subsequent blight damage.

Since maple blight has developed in the past, it has to be assumed that similar outbreaks will occur in the future, although there is no way of knowing their frequency or extent. Past experience indicates that they are relatively rare. However, as has been shown by experience, local damage in such outbreaks can be very severe and no doubt would merit application of direct control measures. Since the primary cause of maple blight is insect defoliation, the obvious point at which to apply direct control is the defoliating insects. The relatively low populations of the insects during the maple blight research and in subsequent years has precluded pursuit of any research on various control techniques. The complex of insects involved and the rather extended period during which their various life stages emerge indicate that development of a relatively simple direct control measure may be very difficult. In any future outbreak of the insects involved in development of maple blight, especially the maple webworm, control development studies would merit research attention.

INTRODUCTION

In 1957 severe mortality and dieback of sugar maple appeared on an area in Florence County, Wis. Maple of all sizes from seedlings and small saplings to saw-log timber were dead, dying, or damaged (fig. 1). The alarmed owners asked several specialists to appraise the situation.

Although maple on the area had been severely defoliated by insects, forest entomologists seriously doubted that this was the primary cause. Other hardwoods on which defoliation had been studied did not die under similar circumstances, and also in some known situations maple had suffered seemingly similar defoliation without mortality. Forest pathologists could not detect any known disease but were of the opinion that a pathogen might be involved. Silviculturists did not note any physical factor that seemed to be the cause, but neither could they rule out this possibility.

Some of these specialists had long and extensive experience with northern hardwoods. All agreed that they had never seen such a situation before. It was particularly alarming because, without knowing the cause, there was no basis for estimating its potential for spread and intensification.

Since the cause was unknown, the problem was given the nondescriptive name of maple blight.

None of the research organizations in the region had adequate resources to undertake intensive studies of the problem. The hardwood industry offered to provide some of the financial support, and the Station assumed responsibility for coordinating the research. Representatives of the Station, industry, and universities met to analyze the problem and develop a program of research. Four areas were recognized as needing attention. These were: (1) An appraisal survey to determine distribution and rate of spread, if any, of the disease, (2) a study of ecological factors that might be the cause, (3) a study of insect relations, and (4) a study of possible disease organisms involved.

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FIGURE 1. — Salvage logging on maple blight area in Florence County, Wis.

The Station agreed to undertake the appraisal survey and the ecological study, supported in part by appropriated funds and in part by the industry-contributed funds. The Station also entered into a cooperative agreement with the University of Wisconsin under which the Station contributed funds to the University, and the University in turn assumed responsibility for conducting the insect and disease organism studies. The funds provided by the Station were not adequate to complete these studies. During the later phases, support was provided for the University by the Wisconsin Conservation Department. The Wisconsin Conservation Department and the Michigan Conservation Department also participated in the detection and appraisal survey effort.

The studies were begun in the spring of 1958 and are now completed. During that time the Station prepared three informal written progress reports, and three meetings were held at which the research workers gave forest land managers the results to date of their work. The primary purpose of this paper is to provide a final report, highlighting and summarizing the more important findings for forest land managers and particularly for those who contributed to and cooperated in work on the problem. Those interested in a more detailed and technical report are referred to University of Wisconsin Bulletin entitled "Studies of Maple Blight," which presents a detailed account of the insect, disease organism, and ecological studies.

Since the maple blight investigation involved several different studies, the body of this paper consists of five sections: one on the surveys and the others on the major areas of study.

With so many workers involved in these studies, a brief summary report cannot specify the precise contribution of each one. Therefore, this paper was prepared as an editorial report, with recognition to the major contributors given in the acknowledgments section and in footnotes rather than in a complex array of authorship for the various sections.

DETECTION AND APPRAISAL SURVEYS

The severe damage caused by maple blight in 1957, plus the fact that the cause of the disease was unknown, indicated that surveys were needed to answer two questions: First, how extensive was the problem — that is, what was the current distribution of maple blight? Second, was the blight spreading and intensifying and, if so, how rapidly? Information on rate of spread and intensification would provide a sound basis for estimating the disease's potential for future damage and hence how much future research effort would be justified and how important it would be to apply any possible control measures.

There were two aspects to the survey program begun in the spring of 1958. One was a detection survey. Since the resources available were limited and also because the Wisconsin Conservation Department and the Michigan Conservation Department both had active and well-organized pest survey organizations functioning in the field, a separate survey for maple blight was not undertaken. Instead, the Conservation Departments in the two States, the National Forests, and interested private northern hardwood timberland owners were provided with instructions on how to recognize possible maple blight areas and how to report such areas through normal channels to the Lake States Forest Experiment Station. The Station then followed up by sending a pathologist who was familiar with maple blight to inspect areas reported to the Station.

The second aspect was an appraisal survey conducted by Station pathologists and collaborating University pathologists. Appraisal surveys to determine whether maple blight was intensifying or spreading were made on the original maple blight area in Florence County, Wis., and also on those new areas that were found in the detection survey.

Detection Survey

During the 1958 and 1959 field seasons 21 reports were received about areas suspected of having maple blight. Five of these were in the Lower Peninsula of Michigan, eight in the Upper Peninsula, and eight in Wisconsin. No reports of possible blight areas have been received since 1959.

Followup examination indicated that none of the Michigan areas had maple blight. In Wisconsin, however, two of the eight areas examined had maple blight. These were in addition to the original area of extensive and severe maple blight in Florence County (fig. 2). The two blight areas found in the course of the detection survey are very small and of minor importance. One, in Iron County, (T. 43 N., R. 1 E., sec. 20 and 35), consists of two small patches — 0.5 acre and 0.9 acre in size — with severe mortality. The second area, in Ashland County, consists of three small patches — 1 acre in T. 43 N., R. 2 W., sec. 6; 0.3 acre in T. 44 N., R. 2 W., sec. 22; and 1.2 acres in T. 42 N., R. 4 W., sec. 2.

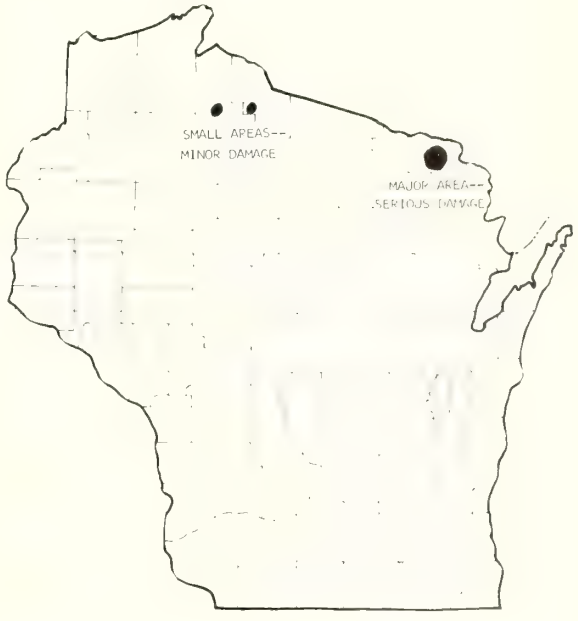

FIGURE 2.—Location of maple blight areas in Wisconsin.

Many of the other suspect areas proved to have maple dieback instead of maple blight. Maple dieback, which is widespread throughout the Lake States and the Northeast, is now causing some concern to land managers. It is regarded as distinctly different from maple blight, however; and care

[1] *Conducted by Dr. Ralph L. Anderson, Lake States Forest Experiment Station, Dr. David W. French, University of Minnesota, and Dr. Gene A. Hedgcock, Michigan Technological University, with the cooperation of the Wisconsin Conservation Department (Mr. Donald Rentlund and Mr. Stanley Banash) and the Michigan Conservation Department (Mr. Norman Smith).*

was taken in the survey followups to distinguish between the two diseases. Dieback is generally limited to the larger overstory trees, progresses rather slowly, and seldom causes mortality. Maple blight, on the other hand, affects trees of all size classes, causes severe mortality, and has other distinctive characteristics such as profuse, epicormic sprouting on affected trees that have not been killed by the disease (fig. 3).

The results of the detection survey were encouraging. They indicated that maple blight was limited to three areas in Wisconsin and that in two of these areas the amount of timber affected was insignificant.

Appraisal Survey

The objective of the appraisal surveys was to determine whether maple blight was spreading outward into new areas and intensifying on those areas with affected trees. Because of substantial differences in the areas on which such surveys had to be made, two methods were used. In Iron and Ashland Counties, where the affected areas usually involved less than an acre, each area was studied intensively. The outermost limits were marked with paint to provide reference points. These were used in later re-examinations to determine whether the blight was progressing into previously unaffected areas. Then practically all living trees within the affected area were examined to determine when injury had first occurred and whether new injury or symptoms were developing — that is, whether the disease was intensifying. To determine when a tree was first injured, the point where a killed portion of the crown joined living tissue was located; then the annual rings laid down on the living portion since the other portion died were counted.

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FIGURE 3. — Maple saplings killed by maple blight. Damage and mortality of small trees is one characteristic of blight that distinguishes it from the more widespread maple dieback problem that is generally limited to larger overstory trees.

Although defoliating insects were not active on these areas at the time they were appraised, an effort was made to determine whether they had been defoliated by checking with Pest Survey personnel and examining such clues as might be found on the plot area; for example, growth rate on brush and understory trees was checked for any acceleration that may have occurred during periods of defoliation.

On the original extensive maple blight area in Florence County, Wis., a substantially different approach to the appraisal had to be made because of the large area involved and the greater complexities. Maple blight symptoms extended over an area of about one township, with concentrated severe damage in a number of local areas involving in aggregate about 1,000 acres and a scattering of lesser damage on intervening areas (fig. 4). Also, the preliminary investigations of the problem had been made on this area; and nearly all of the early research was conducted here. Most of the research workers had established permanent study plots on which they rated the severity of blight damage on affected trees. Thus, information on future intensification of blight would be obtained as a matter of course in the process of the research studies. Most of the survey effort, therefore, was devoted to determining whether the blight was spreading into previously unaffected areas.

The first step was a preliminary aerial survey to roughly map in the areas with obvious maple blight symptoms and to orient the survey crew on the area in general. This was followed by ground mapping conducted by two-man survey crews. The survey crews ran numerous transect lines, starting

in areas of known blight damage and continuing the line outward until they had gone some distance beyond any evident blight symptoms. As the transects were run, the presence or absence of blight and estimated intensity were recorded to provide a basis for later re-examination of the same transects to note any change. Emphasis was placed on locating the outer limits of areas with a low prevalence of blight, since the aerial survey as well as a series of earlier aerial surveys made by the Wisconsin Conservation Department showed the location of the outer limits of severe blight.

The results of the appraisal survey were essentially identical for all maple blight areas. At the time of the initial appraisals in 1958, the general opinion of those making the survey was that the blight was not spreading outward into surrounding healthy stands. A rechecking of the painted boundaries on the small maple blight areas in 1959 and again in 1960 indicated no spread whatsoever. A subsample of the transects on the large maple blight area in Florence County in 1959 and 1960 also showed no evidence of spread. Not all of the transects were rechecked because the evidence showed no need for it.

In 1958 when the first appraisals were made it was not possible to be certain whether blight was intensifying on the previously affected areas. In general, however, the current symptoms found on damaged but still living trees seemed to be the result of previous damage rather than intensification resulting from current activity of the causal agent of blight. Subsequent observations on the small maple blight areas in Iron and Ashland Counties

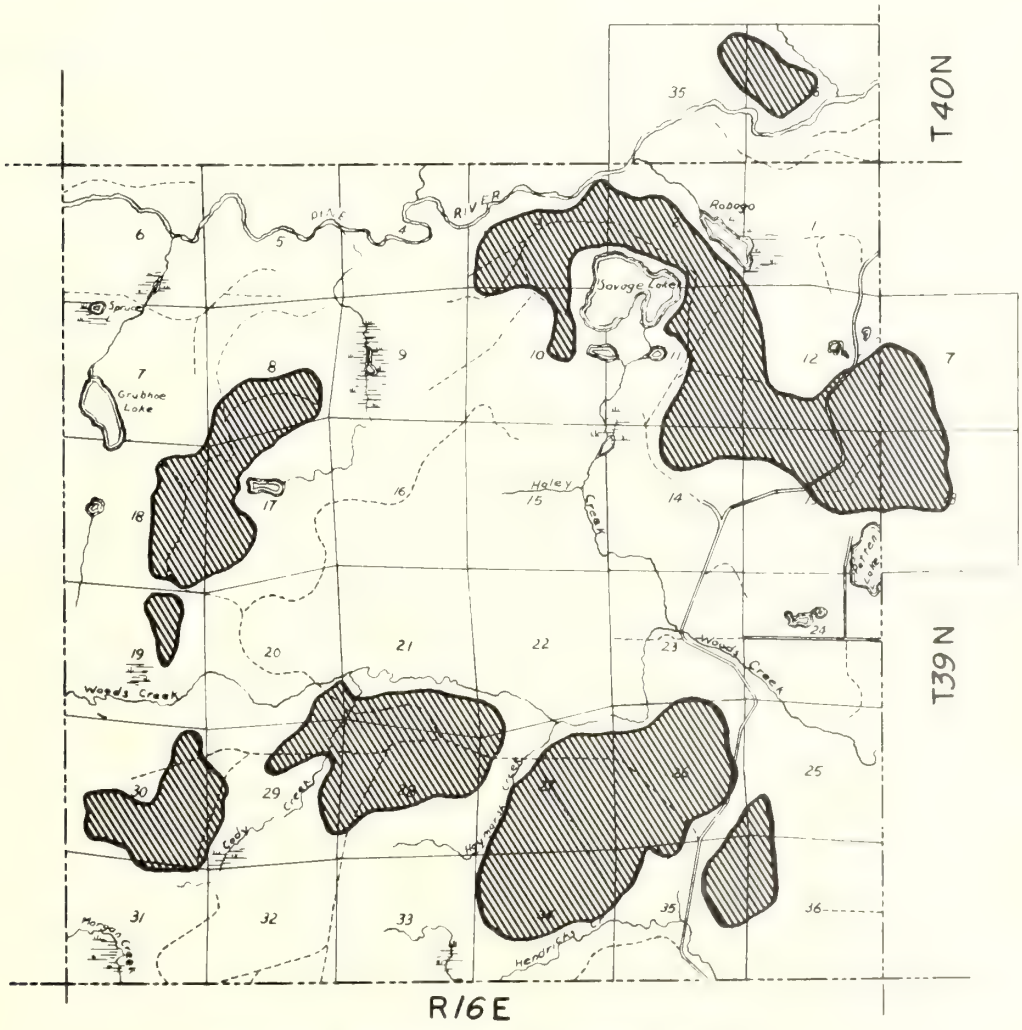

FIGURE 4. — Local distribution of maple blight, Florence County, Wis., 1958.

in 1959 and 1960 showed no evidence of current intensification. Instead, the picture was one of recovery for those trees that had not been killed. Reexamination of plots established by the research workers in their studies on the Florence County area presented the same picture — that is, recovery, not intensification — except for a few individual trees where the continued decline was shown to be due to secondary factors.

A third finding was that all of the areas affected by maple blight had also been infested previously by defoliating insects. In the small maple blight areas the major portion of the damage had occurred in 1957. This agreed well with results obtained by Houston in his disease studies in Florence County (discussed later).

The principal conclusions arrived at from the appraisal survey were as follows:

1. Maple blight symptoms were never found in any area that did not have a history of insect defoliation.

2. In all of the maple blight areas a major portion of the damage and mortality had occurred in 1957, and subsequent to that the picture had been one of recovery.

3. The failure of maple blight to spread and intensify suggested that maple blight was not caused by a highly virulent pathogen.

DEFOLIATION STUDIES[2]

For a variety of reasons all of the research studies conducted on the maple blight problem involved defoliation. Defoliation is the key factor in the development of the maple blight complex. For this reason, research on defoliation is discussed early in this report to orient the reader properly on its significance and to better enable him to interpret its relationship to the other factors on which research was conducted.

The maple blight area in Florence County had been subjected to severe insect defoliation from 1955 to 1957. By 1958, however, when research studies were started, the insect population had collapsed. To study the effects of defoliation under controlled conditions it therefore was necessary to resort to artificial defoliation.

Giese and Kapler's studies were aimed at determining the response of maple to defoliation and whether such defoliation could cause the development of maple blight symptoms. They established a number of defoliation studies during 1958, 1959, and 1960. The principal study was conducted on a stand of saplings growing under a closed overstory. Treatments included complete defoliation, defoliation of the upper two-thirds of the crown, defoliation of the lower two-thirds of the crown, defoliation of the upper one-third of the crown, defoliation of the lower one-third of the crown, and two sets of checks. Neither set was defoliated, but trees in one set were bent over and released in a manner similar to trees that were bent over for defoliation. Similar tests were installed in open-grown stands where maple saplings were the dominant tree cover, and also in a number of different geographic locations. In some of these studies trees were defoliated at weekly intervals throughout the growing season, and some selected trees were defoliated in 2 successive years during the same week of the year.

An additional type of treatment was introduced into studies established in 1960: Individual leaves scattered throughout the crown were removed on the basis of one out of every four, two out of every four, and three out of every four.

The response of sugar maple to defoliation was dramatic. As a result of a single complete defoliation or complete defoliation of a major portion of a tree's crown, all of the recognized maple blight symptoms were created. Except for maple defoliated later than mid-August, trees that were given major defoliation treatments refoliated; but usually such foliage was small and sparse. The year after treatment, those trees were characterized by wilting, severe dieback, heavy epicormic sprouting, and considerable tree mortality — all characteristic symptoms of the maple blight that had developed earlier from natural causes. Even when only portions of a crown were defoliated, those portions developed the blight symptoms.

[2] *Conducted by Drs. Ronald L. Giese and Joseph E. Kapler of the Department of Entomology, and Dr. David R. Houston of the Department of Plant Pathology, University of Wisconsin; and by Darroll D. Skilling, Lake States Forest Experiment Station.*

The principal conclusion is that severe defoliation of sugar maple for 1 year can cause symptom development that is identical with that described for maple blight. Some other interesting findings and conclusions are that defoliation late in the growing season does not cause severe damage; hence, timing of defoliation is critical to the development of blight-type symptoms. Another finding was that even 2 years after defoliation there is a continuing decline of affected trees. A second defoliation, however, 1 year after the first did not seem to increase appreciably the severity of symptom development. Neither did uniform removal of part of the foliage throughout the crown.

The reaction of sugar maple to a single defoliation was much more severe than most people (including entomologists) anticipated on the basis of previous defoliation studies on other species. Two important points are emphasized by this result. First, sugar maple apparently is much more susceptible to defoliation injury than are some other deciduous species; and secondly, timing of defoliation is closely related to the degree of damage caused. In particular, the timing of the defoliation by the insects involved in maple blight is such as to generate maximum damage.

Defoliation studies were conducted as a necessary adjunct to disease research efforts to determine whether a pathogen was involved in the maple blight problem. That is, the detrimental effects of defoliation on host trees could materially affect their response and susceptibility to invasion by pathogens. The studies also helped scientists to distinguish between such symptoms as could be attributed solely to defoliation from those which conceivably could be caused by a pathogen. Dr. Houston's studies did, of course, provide substantial evidence on the effects of defoliation itself. The results were essentially identical with those obtained by the entomologists in their studies.

Houston's defoliation studies were conducted on saplings, both open-grown and understory, and the defoliation schedules employed were very similar to those used by Giese and Kapler. Although the results of the two sets of studies were essentially identical, some differences in certain details provide additional information. Houston did defoliate some trees twice in the same year, and almost all such treated trees were dead the next year. He defoliated selected individual branches on maple trees, and symptom development on those branches was virtually the same as for entire defoliations or defoliations of major portions of the crown. He noted that the amount of terminal bud mortality increased with the date of defoliation from June to early August and then decreased, with the most severe bud mortality occurring on trees defoliated from mid-July to mid-August. Tree death was greatest in the series with the most bud mortality.

In September 1958, Houston observed that an early fall frost injured the new growth on trees that had refoliated; this substantially increased the injury caused by defoliation by destroying much of the bud tissue not yet mature enough to resist frost damage. This type of damage was much more severe on open-grown than on understory trees. His weather records show that temperatures went down much lower in open areas than under an overstory canopy during the fall-frost period. Apparently the effects of fall frost on refoliation tissue that has not yet hardened off may be an important contributing factor to maple blight. The reduced mortality and damage on trees defoliated during the latter part of the summer may be due to their failure to refoliate and, consequently, lack of new bud tissue to be damaged by frost.

Houston noted that mortality of treated saplings was not random among trees given any one treatment and considered this as evidence that a contributing factor other than defoliation may be involved in maple blight mortality. This provided a clue for some of his pathogen studies, which are reported in a later section of this paper.

A defoliation study was also conducted as part of Skilling's research to determine the role of other environmental factors as possible causes of maple blight. His primary purpose was to learn the interrelationships between maple blight and defoliation accompanied by reduced soil moisture. This study, which differed substantially from the other investigations, also provided considerable information on the effects of defoliation alone. The test trees were larger pole-sized trees in a dominant position in the forest canopy and were defoliated from a tractor-mounted ladder instead of by bending them over as was done with the saplings in the other studies (fig. 5). Also, all of his work was conducted on the Argonne Experimental Forest at a considerable distance from any area that had suffered from maple blight. Nevertheless, the results were

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FIGURE 5. — Defoliating a maple to study symptoms caused by defoliation.

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FIGURE 6. — Bunchy appearance of foliage on maple damaged by blight is caused by the fact that foliage is on epicormic sprouts. This is characteristic of trees during early stages of recovery.

essentially identical with those obtained by the other workers. His work also demonstrated that defoliation was *the* most important factor among those he studied in causing maple blight symptoms.

Thus, three essentially independent studies of defoliation of sugar maple all demonstrated that defoliation by itself could cause all of the symptoms associated with the maple blight problem and that, beyond reasonable doubt, defoliation by insects was the principal factor causing the maple blight outbreak. Furthermore, this reaction to defoliation applied to maples over a wide range of tree sizes of all crown classes and over a wide range of sites and environmental conditions. It also appears that refoliation and the consequent incomplete hardening off of buds in the fall made the maple susceptible to frost injury, further aggravating the situation. Circumstantial supporting evidence that defoliation was the primary factor causing maple blight was the fact that, following collapse of the insect populations on the maple blight areas, those trees that had not been killed outright were recovering (fig. 6).

DISEASE STUDIES[3]

The principal objective of pathology research on maple blight was to determine whether a pathogen is a primary factor in causing the disease. This was a key consideration. If a virulent pathogen was involved, there was a strong possibility that sustained spread and intensification would continue until maple blight had caused severe damage throughout major portions of the sugar maple type. On the other hand, if maple blight was not caused by a virulent pathogen, the odds were that (1) the causes involved were unique to certain local situations, and hence, maple blight had much less potential for intensification, or (2) the blight was caused by insects, in which case prospects for controlling occasional epidemics would be better than for a pathogen. Dr. Houston was given responsibility for resolving this important question.

There were two important phases to this work. The first required a careful study of symptom development on individual trees and in local stand areas to determine whether there was any characteristic pattern that provided clues as to the cause of the symptom complex. The second and key phase was to search for pathogens and to test their ability to cause maple blight symptoms on previously healthy trees.

There were several phases to the symptom development studies. The defoliation work previously described provided information on symptoms that could be attributed directly to defoliation damage. Plots were set up in the maple blight area to study the development and progression of symptoms on individual trees and in affected stands. Affected and healthy trees were examined biweekly and selected trees were photographed periodically to obtain a permanent record of symptom progression. The results indicated that most of the damage had been in the past; and there was little evidence of continuing or increasing damage. This, of course, was circumstantial evidence that minimized the possibility of a virulent pathogen being involved. There was some increase in damage during 1958, but this was relatively small compared to what must have happened in the preceding year. And in 1959 and 1960 some of the more severely affected trees died; but again these were relatively few compared to those that had died immediately following the insect defoliation.

Houston also determined what year most of the dieback had occurred in four different localities within the Florence County maple blight area. The time of major damage varied somewhat from one location to another, but the most severe symptom development had occurred during 1956 and 1957. This fits in very well with what most likely happened during the course of the insect epidemic; that is, there would be some variation in the time of onset of severe defoliation in different locales as the insect population built up. The general overall pattern noted in these studies coincides with the survey findings: the general picture following the initial severe damage 1 year after heavy defoliation was one of recovery and hence a strong indication that a virulent pathogen was not involved.

In 1958 when the studies were started it was not known, of course, that this pattern was going to develop. In any case, it still was desirable to make as certain as possible that no virulent pathogen was involved and to learn whether any pathogens, not of a highly virulent nature, might have contributed to the symptom development and mortality. Houston conducted isolation studies from all tissues of affected trees in a search for possible pathogenic fungi or bacteria. Repeated attempts were made from numerous trees and various parts of such trees. When these isolates were grown in culture and studied, none proved to be a fungus or bacteria previously known to cause a serious disease of sugar maple.

Cultures of the various organisms isolated were then used to inoculate healthy sugar maple in a location about 1.7 miles removed from any known maple blight. Inoculations were made at various conceivable points of entry by a pathogen, using a variety of inoculation techniques. None of the organisms tested produced maple blight symptoms. Aside from a little discoloration at the point of inoculation on some of them, the inoculated trees remained healthy.

Tests were also made to determine whether a virus might be involved. These tests were conducted by attempting to transmit mechanically any virus present from affected to healthy trees. Again no symptoms were produced; the possibility that a virulent pathogen was involved seemed small.

[3] *Conducted by Dr. David R. Houston, Department of Plant Pathology, University of Wisconsin.*

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FIGURE 7. — *Armillaria mellea* root rot on maple damaged by blight.

During his studies, Houston noted that on his defoliation plots mortality did not seem to be scattered at random among the trees given any one treatment but rather tended to appear in groups or pockets and that the mortality seemed to be concentrated in the vicinity of previously killed trees or stumps. This suggested that a root rot fungus such as *Armillaria mellea* (Vahl.) Quel. probably contributed to the mortality (fig. 7). The pockets of mortality were originally noted on the trees that were hand-defoliated in 1958. Repeated studies in 1959 and 1960 gave similar results. Examination of the roots and root collar region on these trees showed that *A. mellea* was very common on the dead and dying trees. Stumps of recently cut trees were studied to determine the pattern of *A. mellea* infection on larger trees. Of the maple blight trees salvaged in logging operations, about 70 percent were infected with *A. mellea,* whereas only about 32 percent of the "healthy" trees cut in logging operations were so infected. Houston concluded that, although defoliation is the principal cause of maple blight, *A. mellea* aggravates it or increases mortality and probably accounts for most of the delayed mortality. As previously noted, some mortality continued for about 3 years after the year of most serious damage.

In conclusion, it can be said that the results of the pathology studies supported the results found by others, which indicated that a primary pathogen was not responsible for maple blight. The studies also showed that Armillaria root rot contributed some increase in mortality among the trees weakened by insect defoliation.

The major role played by defoliation in causing maple blight indicates the importance of detailed knowledge about the insects responsible for the defoliation. Even though most entomologists and others were skeptical about insect defoliation being a major factor in the development of maple blight symptoms in Florence County, Wis., the fact that insect defoliation was coincident with maple blight indicated that the only wise course would be to give these insects major attention.

Giese made a detailed study of the defoliating insects that had been present on the area in large numbers during the period of severe defoliation. Three species of insects were primarily involved, two leaf rollers and a webworm. The following is a brief summary of what was discovered about each of these insects:

The first of these to appear during the growing season is a leaf roller named *Sparganothus acerivorana* MacKay. This is a solitary insect, with each individual rolling a leaf on a sugar maple. The insect had not been previously known to be present in this region. Since its discovery in the Florence County maple blight area, it has also been found in some other areas in Wisconsin. The larvae of the insect are solitary feeders and use the rolled leaf only as a retreat and a place for later pupation (fig. 8). They feed on adjacent leaves. Although a considerable number of leaves may be rolled by a high population of these insects, they do not seem to destroy enough leaves to damage sugar maple trees severely. This is true not only because of the number of leaves rolled but also because the affected leaves are more or less scattered throughout the crown. As was pointed out in the defoliation studies, scattered removal of individual leaves did not have much effect on the trees.

FIGURE 8. — Leaf roller, *Sparganothus acerivorana*, one of the three defoliating insects involved in maple blight. (Photo by Robert Martin, formerly with Goodman Division of Calumet and Hecla, Inc.)

The larvae of this insect have completed their feeding and pupate in late June through early July. The adults appear in late July, and mating and oviposition take place in that same season.

Twenty species of parasites were found on this insect. Of these, three species of Hymenoptera accounted for 95 percent of parasitization. The most important predators were spiders, reducing larval population more than all other predators combined.

In 1958 when the studies of this insect were initiated, the previous high population in the area had already collapsed; it is believed this collapse was due to predation and adverse weather conditions.

The second defoliating insect in the seasonal succession is another leaf roller named *Acleris chalybeana* Fern. This species also was previously not known to be present in the Lake States. Since its discovery on the Florence County maple blight area, it has also been noted in a number of other locations in Wisconsin. In many respects, its habits are very similar to those of the other leaf roller already described.

The larvae first appear from early to mid-June, largely in abandoned rolled leaves that were formed by *S. acerivorana*. This second leaf roller feeds in its roll; and once the food in that leaf is exhausted, it then feeds on adjacent leaves. Although in the early stages of its larval cycle this insect commonly uses abandoned leaf rolls, it also rolls its own leaves and thus increases the number of leaves rolled in a given maple stand; this has substantial significance as will be explained later. However, again the amount of feeding and leaf rolling done by this insect does not appear to damage sugar maple substantially in itself. These insects pupate,

[4] *Conducted by Dr. Ronald L. Giese, Department of Entomology, University of Wisconsin, presently on the staff of Purdue University.*

emerge as adults, mate, and oviposit during the same season as described for the other leaf roller.

Parasitism is an important factor, with losses from this cause sometimes accounting for as much as 90 to 99 percent of the larvae. Sixteen different parasites were found, and many of them were the same as those found on the other leaf roller. Predators are also important and probably can cause losses of about the same magnitude as the parasites. Again, spiders were the most common and important predators.

A third leaf roller named *Gracilaria* sp. was also found on the area, but there is no record indicating that this species occurred in high numbers during the period of defoliation that led to development of maple blight.

The third and last of the important defoliating insects to appear during the season is the maple webworm *Tetralopha asperatella* Clem. This insect can attack a number of hardwood hosts, but in the maple blight studies practically all of the defoliation observed was on maples. The maple webworm is a colonizing insect causing major defoliation — that is, removing the foliage almost completely from entire crowns of trees or major portions of crowns when the population is high. It is believed, therefore, that the direct cause of maple blight symptoms that can be attributed to defoliation is a consequence of feeding by the maple webworm.

The first webworm eggs are deposited from mid-June to early July and may continue to be deposited over a period as long as 60 days. The major peaks in egg abundance occurred in early July followed by another peak in late July. A very significant finding was that the only place in which eggs were deposited was in leaves rolled by the leaf-rolling defoliators. Hence, there appears to be a very close tie-in between the two types of insects; that is, evidently a population of leaf rollers is required on an area before there can be any substantial buildup in the population of webworms. Therefore, even though webworms do the damaging defoliation, the leaf rollers are of critical importance because they provide the necessary environment for deposition of webworm eggs and development of the larvae.

To begin with, the webworm larvae feed as leaf skeletonizers on the rolled leaf in which the eggs were deposited. The larvae then act as true webworms by webbing groups of leaves together. In later stages they feed voraciously, and large numbers of leaves are included in the web. Toward the end of the feeding activity, whole branches may be webbed by a single colony. The larvae of this insect, on the average, feed for about 45 days.

Some environmental factors were noted to affect webworm feeding. Webworm development was earlier and more rapid and populations were greater on the more exposed areas than in denser stands where crown closure was nearly complete. Apparently stand openness favors development of populations of this insect. In one area studied, as many as 63 percent of the saplings in the more or less open areas supported webworm colonies; whereas in nearby areas, which were much more densely stocked, less than 1 percent of the saplings were infested. Evidently the higher temperatures in these more open areas permit the insect to complete its life cycle more rapidly before a killing frost. This probably enhances buildup of populations in such areas.

The insect overwinters as a cocoon in the ground, and most of the adults emerge from mid-June to early July. Actually, in 1958 adults emerged over a 60-day period, starting about the first of June; and about 90 percent of the egg laying had been completed by August 15. The long period of time over which adult emergence and egg laying can occur poses problems with respect to any direct control measures that might be contemplated.

Parasites and predators of this insect were also studied. It was found that one species of parasite may parasitize as much as 17 percent of the eggs when there is a high population density. Several parasites and predators are also found to be active against the larvae.

Unquestionably, the maple webworm is the most important sugar maple defoliator with respect to the cause of maple blight. But probably the most significant discovery is the close interrelationship between the leaf rollers and development of a webworm outbreak. The studies indicated that as many as 200 webworms may develop from one rolled leaf.

A general study was also made of insects associated with rolled leaves. This microhabitat proved a favorite one for sucking insects. If a pathogenic virus is ever discovered on sugar maple, it is possible that the rolled-leaf community might well be important with respect to vector transmission of such a virus.

General insect populations present on blight areas as compared to nonblighted areas were sampled and identified. Dr. Roy Shenefelt of the University of Wisconsin did most of the identification work on these collections. Although a very substantial number of insects in great variety were found and analyzed, as of the present time none, aside from the defoliators, has been found to have any close relationship to the development of maple blight. Some of the insects encountered were attracted by the dead and dying trees and are of some importance in the more rapid deterioration of killed timber.

As a consequence of the insect studies made on the maple blight project, the role of defoliators is now well understood; and important complex interrelationships between the various species have been revealed. An important question is posed by what should be done in the event of future outbreaks of these insects that might lead to another maple blight situation. No control studies have been made, largely because of the lack of an outbreak population to work with. The situation appears very complex because of the number of species involved and the extended periods of oviposition and emergence of larvae. If another outbreak occurs, research should attempt to develop control measures.

ECOLOGICAL STUDIES[5]

In addition to insects and disease organisms, other factors in the environment were considered as possible primary or contributing causes to the development of maple blight. Skilling undertook studies in this area, with primary emphasis on the influence of physical factors in the environment, such as stand and site characteristics, and stand history. In 1958 in the Florence County maple blight area, he established a series of fifth-acre plots at 5-chain intervals along random lines running from healthy portions of stands to areas severely affected by maple blight. He established 113 plots. On each plot detailed descriptions were made of stand and site characteristics, history of the area, and the severity of maple blight.

A few of the factors studied did show a relationship to the severity of maple blight. One of these was stand density. About 70 percent of the maple trees on areas of low stand density had severe symptoms compared to 22 percent on areas with high stand density. Density as used here refers to the basal area of the stand. Most of the high prevalence of severe damage was in areas with less than 100 square feet of basal area per acre prior to any salvage operations made as a consequence of maple blight. There also was a relationship with number of trees per acre, stands with more stems having less damage. However, this relationship was not as pronounced as that based on basal area.

Skilling also found a relationship with stand composition; that is, severe maple blight was much more prevalent in those stands in which sugar maple made up more than 50 percent of the volume. In other words, maple blight was less severe in the more mixed stands.

Although the above relationships existed with reference to stand density and composition, some severe damage was found under all conditions. These relationships probably reflect the favorability of the various stand conditions for development of large populations of the defoliating insects.

No relationship was found between tree size, tree age, or site index and susceptibility to maple blight damage. Skilling also examined 20 sample plots that were established in 1948 by the owners for other purposes, on which each individual tree had been classified as to tree vigor. In his reexamination in 1958 there was no relationship between current severity of blight and vigor of trees as recorded 10 years earlier. This also was in line with general observations on the maple blight area at the time of the epidemic.

A detailed study of growth trends on 34 trees indicated no reduction in rate of growth prior to the onset of insect defoliation and maple blight. Apparently there had been no predisposing debilitating factors. Skilling and others also noted that the ground vegetation situation was quite different on severe blight areas than in normal stand situations in that there was a much denser growth of

[5] *Most of the ecological studies were conducted by Mr. Darroll D. Skilling, Lake States Forest Experiment Station.*

some of the ground cover species, such as raspberry. This relationship, however, is believed to be a matter of insect defoliation and maple blight mortality opening up the area, thus making the area more conducive to growth by these species.

A comparison of the cutting practices on various areas under study indicated no relationship between previous logging history and development of maple blight; some areas that had not been cut for 20 years had heavy maple blight mortality, and so did areas that had been cut quite recently. No abnormal amount of logging damage was found on blighted trees nor was there any evidence of fire, windthrow, or sunscald being associated with prevalence of maple blight damage.

Skilling also studied the influence of topography. Considering the relative elevation of each plot to the surrounding area, he found that blight was more severe on what can be referred to as upper flats where about 65 percent of the maple had severe blight; whereas on slopes and lower flats about 40 percent of the maple had severe blight symptoms. He did not find any relationship with aspect or degree of slope. The reason for more blight on upper flats is not definitely known. However, the differences involved with respect to topography and severity of maple blight do not appear to be strong enough to be considered as major factors in the problem.

Climatic factors were also considered. Records were studied from three weather stations. One of these is 13 miles northeast of the blight area, another 9 miles southeast, and the other one 9 miles west. The only suggestion of a weather influence was the fact that in the 10-month period prior to the onset of the severe mortality in 1957, precipitation was 8.3 inches below normal. This opened up the possibility that below-normal moisture could be involved in the development and severity of blight symptoms.

In preceding sections of this report it was suggested that early fall frosts or unusually severe frosts might be responsible for much of the bud dieback that occurs on refoliating trees. The weather records did not show any such frost for 1956 or 1957. However, these weather records do not necessarily establish that such a frost did not occur in the blight area, because such effects are often very localized. Much other evidence suggests that frosts, whether abnormal or normal, very likely do damage buds of trees that have refoliated.

Soil factors were also studied. A substantial number of soil samples, taken from four general locations in the maple blight area, were analyzed. This analysis showed no deficiences in soil nutrients or soil properties, but rather that the soil should be considered as a good hardwood soil. Some fertilization studies were also made on the maple blight area, but no differences were noted in the recovery pattern on these trees as compared to check trees which had received no fertilization.

Houston in his studies of possible pathogens established several plots to observe symptom development. These plots also provided some information on ecological factors. The data indicate that blight was more severe in low-density stands and in stands with a high proportion of sugar maple. Thus, his results in this respect substantiate those found by Skilling. Houston also pointed out that weather records obtained from some of his study areas showed that temperatures during frost periods run lower in more open-grown stands than under closed canopies. This is in line with the general pattern that has been found in the Station's studies of microclimate in relation to white pine blister rust.

In 1959 Skilling started a second major study in which the primary objective was to determine the influence of reduced soil moisture on development of maple blight symptoms. This study was established on the Argonne Experimental Forest, which is about 50 miles west of the Florence County maple blight area; therefore the study was not confounded by natural blight effects in the study area. By 1959 it was well recognized that insect defoliation was possibly a major factor accounting for the onset of maple blight symptoms. Therefore, defoliation had to be taken into account in evaluating the effects of reduced soil moisture. Skilling selected a number of test trees (which have already been referred to in the section of this report pertaining to defoliation studies) and applied various combinations of defoliation and soil moisture reduction; untreated trees were left as checks. A rather complex experimental design was used to enable the investigator to distinguish between effects caused by defoliation alone, by soil moisture reduction alone, or by the two in combination.

Soil moisture was controlled by digging a trench around a tree near the crown periphery and covering the area between the trench and the trunk of the tree with a moisture intercept

barrier. Some of these barriers intercepted and removed all moisture, others only 50 percent. This moisture-control system was put into effect in June of 1959, and the trees were defoliated in August of 1960. Soil moisture was measured periodically to determine the level of moisture prevailing around the roots of each of the trees in the test (fig. 9). Rootlet mortality was also checked in 1961 by sampling feeder roots from each of the trees. The principal problem was that soil moisture under the barriers was not reduced as much as had been anticipated, apparently because of some recharge from below. However, significant reductions in soil-moisture levels were eventually achieved.

The results showed that insect defoliation was definitely the most important of the factors causing maple blight but that reduced soil moisture did contribute by causing some increase in severity of symptoms; that is, trees subjected to a given level of defoliation plus reduced soil moisture had more severe symptoms than trees with the same defoliation but normal soil moisture levels.

In conclusion, it can be said that environmental factors do influence the severity of maple blight and the prevalence of maple blight symptoms, the principal factors being stand density, stand composition, and reduced soil moisture. However, all of these factors are definitely secondary to insect defoliation. The stand density and composition influence, of course, is believed to be indirect in that it affects insect population buildup.

F-506144

FIGURE 9. — Taking samples from soil beneath a ram intercept barrier to determine soil moisture level.

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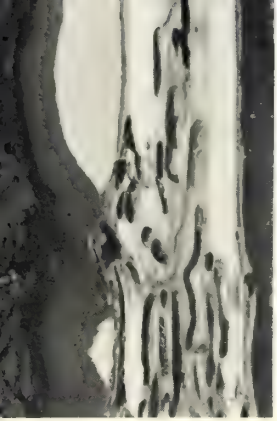

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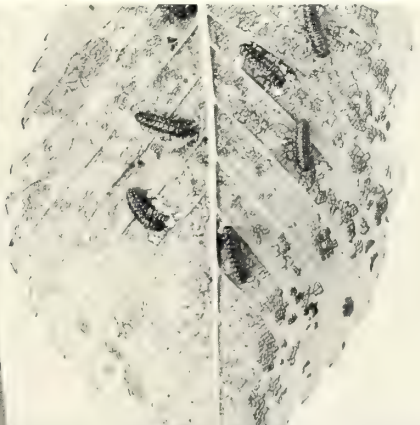
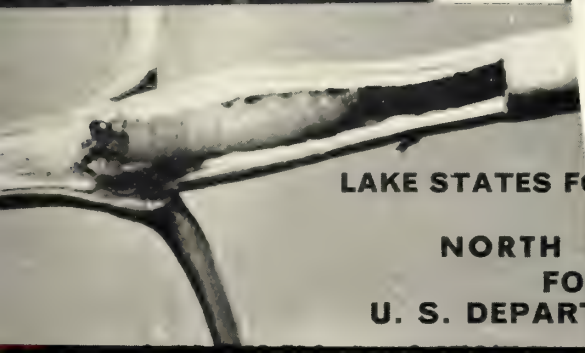
H.J. MacAloney and H.G. Ewan





LAKE STATES FOREST EXPERIMENT STATION
and
NORTH CENTRAL REGION
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

FOREWORD

In the U.S. Forest Service, responsibilities for the forest insect surveys and research are assigned respectively to the North Central Regional Office and the Lake States Forest Experiment Station. The Region conducts detection and evaluation surveys of insect infestations, initiates control measures on National Forests, and provides technical assistance on control programs to private, State, and other Federal land-managing groups when appraisals indicate that control measures are justified. The Station conducts research on the biology, ecology, and control of insects. Results of the research are published periodically and are summarized in the Station's annual report.

Prompt and correct identification and reporting of forest insects can do much to indicate the location of infested areas where control measures are needed. This publication, prepared by the Station and financed by the Region, is a companion paper to Station Paper 100, "Identification of Conifer Insects by Type of Tree Injury, Lake States," by H. J. MacAloney and D. C. Schmiege. Recognizing the need for information to enable field identification of injury by hardwood insects, Dr. MacAloney undertook the preparation of this paper following his retirement from active duty in November 1961. In the preliminary stages, Dr. H. G. Ewan, recently deceased, contributed greatly from his knowledge and experience in the Region.

As an aid to identification a large number of photographs have been included. Many of them were obtained from agencies outside the Forest Service. Permission to use them is gratefully acknowledged.

CONTENTS

	Page
Introduction	1
Key and Table	2
Key Based on Type of Tree Injury	4
Table 1. — Free-Feeding Defoliators — Clues Leading to Their Identification	9
Defoliators	12
Free-Feeding Species	12
Forest Tent Caterpillar *(Malacosoma disstria)*	12
Green-Striped Mapleworm *(Anisota rubicunda)*	12
Orange-Striped Oakworm *(Anisota senatoria)*	13
Variable Oak Leaf Caterpillar *(Heterocampa manteo)*	13
Saddled Prominent *(Heterocampa guttivitta)*	14
Yellow-Necked Caterpillar *(Datana ministra)*	15
Walnut Caterpillar *(Datana integerrima)*	15
Red-Humped Oakworm *(Symmerista canicosta)*	16
Orange-Humped Mapleworm *(Symmerista leucitys)*	16
White-Marked Tussock Moth *(Hemerocampa leucostgima)*	17
Gypsy Moth *(Porthetria dispar)*	17
Spring Cankerworm *(Paleacrita vernata)*	18
Fall Cankerworm *(Alsophila pometaria)*	18
Bruce Spanworm *(Operophtera bruceata)*	18
Elm Spanworm *(Ennomos subsignarius)*	19
Linden Looper *(Erannis tiliaria)*	20

(Continued)

Cover: Examples of hardwood insects or their damage to trees. Top left — locust borer; top right — woolly elm aphid; center left — white-marked tussock moth; center right — basswood leaf miner; bottom left — boxelder twig borer; bottom right — elm leaf beetle.

Cecropia Moth *(Hyalophora cecropia)* 20
Polyphemus Moth *(Antheraea polyphemus)* 21
Mourning-Cloak Butterfly (Spiny Elm Caterpillar) *(Nymphalis antiopa)* 21
Birch Sawfly *(Arge pectoralis)* 21
Elm Sawfly *(Cimbex americana)* 22
Brown-Headed Ash Sawfly *(Tomostethus multicinctus)* 22
Black-Headed Ash Sawfly *(Tethida cordigera)* 22
Willow Sawfly *(Nematus ventralis)* 23
Mountain-Ash Sawfly *(Pristiphora geniculata)* 23
Walkingstick *(Diapheromera femorata)* 24
June Beetles (Leaf Chafers) *(Phyllophaga* spp.) 24
Blister Beetles (Meloidae) 25
Webworms, Tent-Makers, Leaf Rollers 26
Eastern Tent Caterpillar *(Malacosoma americanum)* 26
Prairie Tent Caterpillar *(Malacosoma lutescens)* 26
Fall Webworm *(Hyphantria cunea)* 27
Oak Webworm *(Archips fervidanus)* 27
Ugly-Nest Caterpillar *(Archips Cerasivoranus)* 27
Maple Leaf Rollers *(Sparganothis acerivorana)* 29
(Acleris chalybeana) 29
Maple Webworm *(Tetralopha asperatella)* 29
Fruit-Tree Leaf Roller *(Archips argyrospilus)* 29
Large Aspen Tortrix *(Choristoneura conflictana)* 30
Aspen Leaf Roller *(Anacampsis innocuella)* 30
Basswood Leaf Roller *(Pantographa limata)* 31
Leaf Miners and Skeletonizers 32
Aspen Leaf Miner *(Phyllocnistis populiella)* 32
Aspen Blotch Miner *(Lithocolletis tremuloidiella)* 32
Solitary Oak Leaf Miner *(Cameraria hamadryadella)* 32
Gregarious Oak Leaf Miner *(Cameraria cincinnatiella)* 32
Birch Skeletonizer *(Bucculatrix canadensisella)* 33
Oak Skeletonizer *(Bucculatrix ainsliella)* 33
Birch Leaf Miner *(Fenusa pusilla)* 33
Elm Leaf Miner *(Fenusa ulmi)* 34
Locust Leaf Miner *(Xenochalepus dorsalis)* 35
Basswood Leaf Miner *(Baliosus ruber)* 36
Cottonwood Leaf Beetle *(Chrysomela scripta)* 37
Cottonwood Leaf-Mining Beetle *(Zeugophora scutellaris)* 37
Elm Leaf Beetle *(Galerucella luteola)* 37

Gall Makers 38
Psyllids 39
Hackberry Nipple Gall *(Pachypsylla celtidismamma)* 39
Aphids 39
Poplar Vagabond Aphid *(Mordwilkoja vagabunda)* 39
Poplar Petiole Gall Aphids *(Pemphigus populicaulis)* 40
(Pemphigus populi-globuli) 40
(Pemphigus populi-transversus) 40
Moths 40
Aspen Petiole Gall Moth *(Ectoedemia populella)* 40
Mites 41
Ash Flower-Gall Mite *(Eriophyes fraxiniflora)* 41
Maple Bladder-Gall Mite *(Vasates quadripedes)* 41
Beetles 42
Poplar-Gall Saperdas *(Saperda moesta)* 42
(Saperda concolor) 42
Gall-Making Maple Borer *(Xlyotrechus aceris)* 42
Poplar-and-Willow Borer *(Sternochetus lapathi)* 43
Gall Wasps 43
Gouty Oak Gall *(Callirhytis punctata)* 43
Horned Oak Gall *(Callirhytis cornigera)* 43
Ribbed Oak Gall *(Andricus gemmarius)* 44
Oak Fig Gall *(Biorhiza forticornis)* 44
Oak Flake Gall *(Neuroterus floccosus)* 45
Large Oak-Apple Gall *(Amphibolips confluentus)* 46

Sucking Insects 46
Aphids 47
Woolly Elm Aphid *(Eriosoma americanum)* 47
Woolly Apple Aphid *(Eriosoma lanigerum)* 47
Woolly Elm Bark Aphid *(Eriosoma rileyi)* 47
Scales 47
European Elm Scale *(Gossyparia spuria)* 47
Elm Scurfy Scale *(Chionaspis americana)* 48
Maple Leaf Scale *(Pulvinaria acericola)* 48
Cottony Maple Scale *(Pulvinaria innumerabilis)* 48
Oystershell Scale *(Lepidosaphes ulmi)* 50
San Jose Scale *(Aspidiotus perniciosus)* 50
Putnam Scale *(Aspidiotus ancylus)* 50
Terrapin Scale *(Lecanium nigrofasciatum)* 51
European Fruit Lecanium *(Lecanium corni)* 51
Golden Oak Scale *(Asterolecanium variolosum)* 51
Lace Bugs 52
Elm Lace Bug *(Corythucha ulmi)* 52
Sycamore Lace Bug *(Corythucha ciliata)* 52

Bud, Twig, Branch, and Stem Borers 53
Buds and Twigs 54
Maple Bud Borers *(Proteoteras* spp.) 54
Boxelder Twig Borer *(Proteoteras willingana)* 54
Locust Twig Borer *(Ecdytolopha insiticiana)* 55
Poplar Twig Borer *(Oberea schaumii)* 55
Twig Pruner *(Elaphidion villosum)* 55
Birch and Beech Girdler *(Xylotrechus quadrimaculatus)* 56
Larger Branches and Stems 57
Eastern Ash Bark Beetle *(Leperisinus aculeatus)* 57
White-Banded Ash Bark Beetle *(Leperisinus fasciatus)* 57
Cambium miner *(Phytobia pruinosa)* 58
Bronze Birch Borer *(Agrilus anxius)* 58
Bronze Poplar Borer *(Agrilus liragus)* 58
Two-Lined Chestnut Borer *(Agrilus bilineatus)* 58
Ash Borer *(Podosesia syringae fraxini)* 59
Maple Callus Borer *(Sylvora acerni)* 60
Carpenterworm *(Prionoxystus robiniae)* 61
Oak Timberworm *(Arrhenodes minutus)* 61
Black Carpenter Ant *(Camponotus pennsylvanicus)* 62
Sugar-Maple Borer *(Glycobius speciosus)* 63
Red-Oak Borer *(Romaleum rufulum)* 63
White-Oak Borer *(Goes tigrinus)* 64
Poplar Borer *(Saperda calcarata)* 64
Cottonwood Borer *(Plectrodera scalator)* 65
Locust Borer *(Megacyllene robiniae)* 65
Elm Borer *(Saperda tridentata)* 66
Banded Ash Borer *(Neoclytus capraea)* 66
Red-Headed Ash Borer *(Neoclytus acuminatus)* 66
Columbian Timber Beetle *(Corthylus columbianus)* 67
Ambrosia Beetles *(Trypodendron, Xyleborus, Anisandrus* spp.) 67

Disease Vectors 68
Dutch Elm Disease 68
Small European Elm Bark Beetle *(Scolytus multistriatus)* 68
Native Elm Bark Beetle *(Hylurgopinus rufipes)* 68
Oak Wilt 69
Smaller Oak Bark Beetle *(Pseudopityophthorus minutissimus)* 69
Phloem necrosis 69
Elm Leafhopper *(Scaphoideus luteolus)* 69

Species Not Yet Reported 70

Bibliography 70

INTRODUCTION

The forest history of the North Central States is similar to that of many other regions in the United States. Extensive stands of second growth followed logging and fire. Type distribution was greatly altered; low-grade hardwoods often succeeded over large areas when the original conifers were removed. As a result, about three-fourths of the commercial forest acreage in the Lake States is in the hardwood types. The distribution is approximately: northern hardwoods, 9.6 million acres; oak, hickory, elm, cottonwood, and ash, 11.5 million; and aspen-birch, 18.0 million acres. In addition, on the Northern Great Plains there are about 750,000 acres of natural hardwood growth and 133,400 acres in shelterbelt plantings, which include hardwood species.

These hardwood forests are subject to attack by a large number of potentially dangerous insect species, practically all of them native to the region. While tree damage, generally speaking, is not so serious as in conifer stands, many of the hardwood insect species present serious protection problems.

The most noticeable type of damage is the direct consumption of the foliage; this includes complete foliage destruction by the so-called "free-feeders" as well as partial destruction by miners, skeletonizers, rollers, and webbers. Most hardwood hosts can withstand several years of attack, especially if the trees are vigorous and are growing on good sites. However, defoliation at a critical time during the growing season may seriously weaken or kill trees. The growth rate will decrease and tree vigor may decline, making the trees more susceptible to attack by sucking and wood-boring insects. The damage caused by these latter insects may not be noticed until the trees are in an advanced stage of decline and a reduction in timber values has already occurred.

This report is designed primarily to assist the practicing forester in *identifying* damaging insect species. Both the key and table presented in the next section and the discussions of each insect dwell mainly on the type of injury that can be observed with the unaided eye; but some information is also given on the life cycle. Many photographs are included to illustrate the various types of injury. For the free-feeding species, photographs of the feeding stages are also used.

Included are a number of insects (as well as two species of mites) that are not important from the standpoint of economic damage. However, they do become prevalent at times and are a cause of concern to campers, resort owners, and residents as well as the timberland operators. Some insects that are primarily agricultural in scope — such as grasshoppers — occasionally injure hardwoods. As a rule, this damage is found near agricultural areas and is easily identifiable by the presence of the insects themselves.

No attempt has been made to recommend control or corrective measures. Where heavy infestations occur, direct measures through the application of insecticides are usually considered advisable. In recent years a number of new insecticides have appeared on the market. State laws govern their use, and information on their adaptability can be obtained from

the State Entomology Department. Prevention of population build-up through silvicultural practices designed to bring about forest conditions unfavorable to the development of outbreaks should be an integral part of timber management plans.

A brief bibliography is included at the end of the report for the reader who may want additional information on the insects discussed here.

KEY AND TABLE

Obviously a key for identifying insects by type of tree injury does not follow normal taxonomic patterns; type of damage is not related to insect order, family, or even genus. Thus the damage key presented here "crosses" all taxonomic classifications. It is not intended to be all-comprehensive, but rather to supply a means for field identification. Since there are literally thousands of species that live on hardwoods, the key, with about 100 species, is far from complete. An attempt has been made, however, to include those species which have in the past caused damage or which have noticeable feeding habits. Some insect vectors of diseases affecting forest trees in the north-central region are mentioned in the general discussion but are not included in the key.

Since tree damage is usually clearcut, most individual species can be identified with a reasonable degree of confidence by using this key. But some species do not lend themselves to separation by types of injury because they damage trees in much the same way. For example, the injury caused by the free-feeding defoliators is destruction of the foliage by chewing. Usually this destruction is not sufficiently characteristic to separate the many individual species that cause it. For these insects, therefore, a table was developed to separate the individual insects by period when defoliation is most noticeable, favored hosts, and feeding habits and feeding stages. This table is presented on the pages following the key.

Most of the species are found throughout the region in greater or less abundance. Some species are of more importance in one specific area, such as the green-striped mapleworm in the northern forest or the leaf beetles in the shelterbelts.

For the benefit of those not accustomed to using a key such as shown here, an example follows:

Assume that slight swellings are noticeable on the current season's twigs of quaking aspen. Item 1 in the key shows all damage is divided into two groups: (1) Foliage eaten or otherwise damaged and (2) other tree parts damaged. In our example the twigs are damaged, which leads us to item 4 in the key.

Two choices are given in item 4: Twigs, branches or small stems with (1) typical galls or swellings, or (2) with various scales, slits, tunnels, holes, scars, varnish (discolored sap on bark), or swellings which are not typical galls. The damage consists of small swellings that are not typical galls so we refer to item 25.

Here again we have two choices: (1) Injury to buds, twigs, and small branches and (2) injury to larger branches and stems. The damage occurs in the twigs and, therefore

item 26 is selected. Since the host is *not* maple we take the second choice which leads to item 27.

Inspection of the two choices in item 27 eliminates the first since there is no evidence of scales on the bark. Selection, therefore, is the second choice covering injury due to tunneling in the current season's twigs; this refers us to item 37. The insects concerned are called twig borers. The key further states that if aspen is the tree species attacked, our insect is the poplar twig borer. A reference to the Table of Contents shows that description of the damage and of the insect itself can be found on page 55.

It must be emphasized that positive identification, especially for the defoliators, may require detailed examination by a trained entomologist and recourse to definitive taxonomic keys. Whenever possible, particularly if the collector is in doubt concerning the identity of an insect, specimens should be sent to the State Entomologist for determination and for suggestions on control.

A few terms that may not be familiar to all readers are defined:

Larva. — The immature stage between the egg and the pupa of an insect having complete metamorphosis (complete when a pupa is present).

Instar. — The period or stage between larval molts.

Pupa. — The stage between the larva and the adult; a period of marked developmental changes.

Crawler. — A newly hatched scale insect.

Nymph. — An immature, wingless form, sometimes closely resembling the adult, such as the walkingstick.

Caterpillar. — The larva of a moth or butterfly.

Leaf miner. — A larva that lives in and feeds on the tissues between the upper and lower leaf surfaces.

Leaf skeletonizer. — A larva that feeds on the external tissues of the leaf surface.

Leaf roller, leaf tier. — A larva that feeds on the tissues of a leaf rolled or tied with silken strands.

Leaf curl. — Distortion of a leaf due to the feeding activity of a sucking insect.

Free-feeding defoliators. — Those insects that feed on the foliage without the protection of tents, webs, mines, rolled leaves, etc.

Solitary. — Feeding habitually alone, not in groups or colonies.

Gregarious. — Feeding in groups or colonies.

Frass. — Refuse, either excrement or sawdust or a mixture, expelled by feeding insects.

Thorax. — The body division behind the head, which bears the wings and the true legs.

Wing covers. — Hard coverings (elytra) on beetles to protect the membranous true wings.

Dorsal. — Pertaining to the upper surface or back of an insect.

Ventral. — Pertaining to the under surface or the abdomen of an insect.

Key Based on Type of Tree Injury

1. Foliage eaten or otherwise damaged 2
1. Other tree parts damaged; sometimes wilting and death of foliage occurs 4

2. Foliage eaten — entire leaves or parts of leaves (does not include mining, skeletonization, webbing, tenting, leaf rolling, galls, discolored spots, fleck, or punctures, etc.) .....See table 1 — FREE-FEEDING DEFOLIATORS
2. Foliage damaged — mining, skeletonization, webbing, tenting, leaf rolling, galls, discolored spots, flecks, or punctures, etc. 3

3. Partial to complete injury of leaf tissues associated with mining, skeletonization, webbing, tenting, leaf rolling, etc. 11
3. Partial injury of leaf tissues by galls, discolored spots, flecks, punctures, etc. 15

4. Twigs, branches, or small stems with typical galls or swellings 5
4. Twigs, branches, or stems with various scales, slits, tunnels, holes, scars, varnish (discolored sap on bark), swellings (not typical galls) 25

5. Galls on twigs and small branches of oaks 6
5. Galls on twigs, branches, or small stems of other hardwoods 9

6. Galls apparently developing as single swellings 7
6. Galls developing individually but in well-defined masses 8

7. Twigs with much-enlarged, rough, woody swellings composed of numerous galls fused together .....GOUTY OAK GALL
7. Twigs with much-enlarged swellings with hollow, conelike horns .....HORNED OAK GALL

8. Conical, strongly ribbed galls, about ⅛ inch in diameter, in masses along cracks in the bark .....RIBBED OAK GALL
8. Bladderlike growths, ¼ to ½ inch in diameter, in dense clusters around twigs .....OAK FIG GALL

9. Galls on twigs and branches of red maple .....GALL-MAKING MAPLE BORER
9. Galls on twigs or stems of root suckers or seedling stock of aspen 10

10. Swelling usually smooth on living twigs or on the upper parts of stems; egg pockets in single, horseshoe-shaped incisions in bark .....Two species, POPLAR-GALL SAPERDAS
10. Swellings usually knotty at base of stems with broken places in bark through which frass is pushed; groups of eggs in slits in bark .....POPLAR-AND-WILLOW BORER

11. Several leaves or branches with tent or webbing 12
11. Leaves mined, skeletonized, rolled, or tied together 14

12. Tents formed in branch forks ..EASTERN TENT CATERPILLAR
12. Webs on branches, enclosing foliage 13

13. Aspen — only a few leaves webbed together at branch tips .....PRAIRIE TENT CATERPILLAR

13. Various hosts — few to many leaves webbed together:
    Several hosts — webs present July to October ..FALL WEBWORM
    Oaks — webs present spring to early summer ....OAK WEBWORM
    Cherry — webs present spring to early summer .....UGLY-NEST CATERPILLAR
    Maple — webs present in midsummer .....MAPLE WEBWORM

14. Leaves individually rolled or tied with silk:
    Numerous hosts — feeding damage in May and early June .....FRUIT-TREE LEAF ROLLER
    Aspen:
      Leaves rolled in spring .....ASPEN LEAF ROLLER
      Leaves rolled in July .....LARGE ASPEN TORTRIX
    Basswood — leaves rolled in late summer .....BASSWOOD LEAF ROLLER
    Maples — leaves rolled in May and June .....Two species, MAPLE LEAF ROLLERS

14. Leaves mined or skeletonized:
    Aspen:
      Blotchy mines in late June and early July and again in August .....ASPEN BLOTCH MINER
      Labyrinthine mines in July .....ASPEN LEAF MINER
      Skeletonization of lower surface by beetle larvae in early summer .....COTTONWOOD LEAF BEETLE
      Mines in upper leaf tissues by beetle larvae in June .....COTTONWOOD LEAF-MINING BEETLE
    Birch:
      Leaves mined by early stage moth larvae in early July; later stages skeletonize lower leaf tissues; one generation per year .....BIRCH SKELETONIZER
      Blotchy mines by sawfly larvae in June and again in midsummer; two or more generations per year .....BIRCH LEAF MINER
    Oak·
      Leaves skeletonized by moth larvae early in July and again in late August and September ..OAK SKELETONIZER
      Solitary mines in each leaf by moth larvae in July .....SOLITARY OAK LEAF MINER
      Gregarious mines, several moth larvae in each mine, in July .....GREGARIOUS OAK LEAF MINER
    Basswood:
      Leaves skeletonized by beetles in late June and July; mined by larvae in late July and August .....BASSWOOD LEAF MINER
    Elm:
      Leaves skeletonized by larvae in early summer .....ELM LEAF BEETLE
      Leaves mined by sawfly larvae in late May and early June .....ELM LEAF MINER

14. (Cont'd.)

Black locust:
Lower leaf surface skeletonized by beetles in spring; mining by larvae during the summer ..... LOCUST LEAF MINER

15. Leaves with galls 16
15. Leaves with discolored spots or flecks, edges of leaves sometimes twisted or curled 24

16. Galls on foliage of oak 17
16. Galls on foliage of other species 19

17. Large, globular galls, usually single, green or brown, up to 2 inches in diameter; on several species in the red oak group ..... LARGE OAK-APPLE GALL
17. Small galls, usually numerous, up to ½ inch in diameter 18

18. Hemispherical galls, about ⅛ inch in diameter, covered with white hairs; many galls on leaf undersurface causing curling. Swamp white oak a favored host ..... OAK FLAKE GALL
18. Reddish bladderlike galls in dense clusters, ¼ to ½ inch in diameter along central vein of leaf undersurface. Mostly on white oaks ..... OAK FIG GALL

19. Small galls about ⅛ inch in diameter and bladderlike or nipplelike in form on maple or hackberry leaves 20
19. Galls up to 2 inches in diameter on ash or aspen leaves 21

20. Galls on maple leaves, bladderlike in form and mostly on the upper surface; color light green at first, then changing to reddish and black ..... MAPLE BLADDER-GALL MITE
20. Galls on hackberry leaves; nipplelike in form on the lower surface with depression on upper surface; color light green ..... HACKBERRY NIPPLE GALL

21. Distorted galls on ash leaves, formed in the male flowers and ranging from ½ to 2 inches in diameter .. ASH FLOWER-GALL MITE
21. Galls on aspen leaves 22

22. Twisted or coiled galls, up to 2 inches in diameter, involving leaves at tips of twigs; green at first, dark brown to black when mature ..... POPLAR VAGABOND APHID
22. Globular or semiglobular galls, usually at junction of petiole and leaf proper but sometimes midway on petiole.... 23

23. Globular galls at junction of petiole and leaf proper, up to ⅜ inch in diameter ..... ASPEN PETIOLE GALL MOTH
23. Semiglobular galls, usually at junction of petiole and leaf proper but sometimes midway on petiole, ½ inch or more in diameter ..... Three species, POPLAR PETIOLE GALL APHIDS

24. Leaves with discolored spots or flecks .. Two species, LACE BUGS
24. Leaves with edges sometimes twisted or curled, but not rolled ..... Three species, WOOLLY APHIDS

25. Injury to buds, twigs, and small branches 26
25. Injury to larger branches and stems 38

26. Buds and leaf stalks on sugar maple mined and killed, usually causing forked growth ..... MAPLE BUD BORERS
26. Twigs and small branches of other hardwoods injured by scale or boring insects 27

27. Bark of new and old growth infested with scales of varying sizes and colors 28
27. Pith or center of twigs of current season tunneled 37

28. Scales with marginal cottony or waxy secretion 29
28. Scales without marginal secretion 32

29. Scales with cottony masses, looking like partially popped popcorn 30
29. Scales with waxy secretion 31

30. Scales dark purple, 3/10 inch long ..... MAPLE LEAF SCALE
30. Scales brown, ¼ inch long ..... COTTONY MAPLE SCALE

31. Scales oval, reddish brown with white, waxy, marginal filaments ..... EUROPEAN ELM SCALE
31. Scales pear-shaped, usually dirty-white with grayish secretion ..... ELM SCURFY SCALE

32. Scales oystershell-shaped, light to dark brown in color ..... OYSTERSHELL SCALE
32. Scales circular, variously colored, or pitted 33

33. Scales greenish gold in color; small gall-like pits in bark ..... GOLDEN OAK SCALE
33. Scales reddish brown or gray in general color 34

34. Scales reddish brown 35
34. Scales grayish 36

35. Scales with a black band or mottling and without powdery covering ..... TERRAPIN SCALE
35. Scales without bands but often with a powdery covering ..... EUROPEAN FRUIT LECANIUM

36. Scales light gray with a depressed yellow ring in center ..... SAN JOSE SCALE
36. Scales dark gray with a reddish center ..... PUTNAM SCALE

37. Tunnels in center of current season's twigs, causing slight swellings; injury chiefly to nursery stock and small saplings ..... TWIG BORERS
Boxelder ..... BOXELDER TWIG BORER
Black locust ..... LOCUST TWIG BORER
Aspen ..... POPLAR TWIG BORER
37. Twigs pruned or girdled; injury chiefly to branches up to 2 inches:
Oak ..... TWIG PRUNER
Birch, beech, and maple ..... BIRCH AND BEECH GIRDLER

38. Galleries in inner bark or on surface of wood 39
38. Galleries in wood itself 41

39. Characteristic bark beetle tunnels — egg galleries forked and across grain of wood, larval tunnels lengthwise ..... ASH BARK BEETLES
39. Tunnels superficial; serpentine or meandering 40

40. Serpentine galleries extending lengthwise of the bole, old attacks appearing in cross section as shallow, stained galleries ..... CAMBIUM MINER

40. Meandering galleries on surface of wood and in outer layers of sapwood, with hibernating chambers often a half-inch deep; wood not stained:
    - Oak, beech, eastern hophornbeam ..... TWO-LINED CHESTNUT BORER
    - Birch ..... BRONZE BIRCH BORER
    - Aspen ..... BRONZE POPLAR BORER

41. Injury mainly in base of trees 42

41. Injury mainly in upper part of trunk or in larger branches 45

42. Galleries in heartwood of old or low-vigor trees, usually in decayed areas or in tunnels made by other insects ..... BLACK CARPENTER ANT

42. Galleries in sound wood of living trees; cast pupal shells protruding from emergence holes 43

43. Individual galleries and emergence holes large, about ½ inch in diameter; larvae 2 to 3 inches long ..... CARPENTERWORM

43. Individual galleries and emergence holes small, about ⅛ inch or less in diameter: larvae ½ to ¾ inch long 44

44. Ashes attacked — young trees preferred; full-grown caterpillars about ¾ inch long ..... ASH BORER

44. Maples attacked — larger trees preferred; full-grown caterpillars about ½ inch long ..... MAPLE CALLUS BORER

45. Chief evidence of attack — egg slits cut into inner bark, boring dust, sap leakage, larval galleries in sapwood or heartwood irregularly winding, emergence holes ¼ to ½ inch in diameter:
    - Sugar maple ..... SUGAR-MAPLE BORER
    - Quaking aspen ..... POPLAR BORER
    - Cottonwood ..... COTTONWOOD BORER
    - Black locust ..... LOCUST BORER
    - Red oak ..... RED-OAK BORER
    - White oak ..... WHITE-OAK BORER
    - Elm ..... ELM BORER
    - Ash ..... BANDED ASH BORER or RED-HEADED ASH BORER

45. Chief evidence of attack or emergence — small cylindrical pinholes up to ⅛ inch in diameter; larval galleries deep in wood 46

46. Pinholes about ⅛ inch in diameter; galleries usually in recently felled or in dying trees; larval tunnels usually single and running in all directions; wood not stained ..... OAK TIMBERWORM

46. Pinholes about 1/16 inch in diameter; larval galleries stained dark brown or black by ambrosial fungus 47

47. White oaks; sapwood of living trees preferred ..... COLUMBIAN TIMBER BEETLE

47. Birch, oak, maple, elm; sapwood and heartwood of dying or recently cut trees preferred ..Three species, AMBROSIA BEETLES

Table 1 — Free-Feeding Defoliators — Clues Leading to Their Identification

Period defoliation is most noticeable	Favored hosts	Description of feeding habits and feeding stages	Insect species
MOTHS AND BUTTERFLIES (LEPIDOPTERA)			
Mid-May to mid-June	Aspen, sugar maple	Gregarious; a silken mat, not a tent. Pale bluish caterpillar with a row of keyhole-shaped white dorsal spots; full grown, 2 inches.	Forest tent caterpillar *(Malacosoma disstria)*
May to June	Cherry	Gregarious; free feeding, using tent in branch fork when at rest. Caterpillar deep black in general body color, with broad white dorsal stripe and pale blue lateral spots; full grown, 2 to 2½ inches.	Eastern tent caterpillar *(Malacosoma americanum)*
June to October, (a partial second generation)	Red maple	Solitary. Striped, yellowish-green caterpillar with cherry-red head; full grown, 1½ inches.	Green-striped mapleworm *(Anisota rubicunda)*
Mid-May to early June	Elm, birch, maple, oak	Solitary; both species usually present and difficult to distinguish in the field. Vari-colored inchworms; full grown, 1 inch.	Spring cankerworm *(Paleacrita vernata)* Fall cankerworm *(Alsophila pometaria)*
June to early July	Aspen, sugar maple	Solitary. Green inchworms; full grown ¾ inch. Sometimes found with spring and fall cankerworms.	Bruce spanworm *(Operophtera bruceata)*
June to mid-July	Oak, birch	Solitary. Dusky, hairy caterpillar, head with yellow markings; full grown 1½ to 2½ inches.	Gypsy moth *(Porthetria dispar)*
May to September, two generations	Elm, aspen, willow	Gregarious. Black, spiny caterpillar with many white dots; full grown, 2 inches.	Mourning-cloak butterfly — spiny elm caterpillar *(Nymphalis antiopa)*
June to early July	Basswood, elm	Solitary. Bright, yellow inchworms, with black lines; full grown, 1½ inches.	Linden looper *(Erannis tiliaria)*

(Table continued on next page)

Period defoliation is most noticeable	Favored hosts	Description of feeding habits and feeding stages	Insect species
June to mid-July	Basswood, elm, aspen, maple	Solitary; leaves skeletonized early, then complete defoliation. Tufted, creamy-yellow caterpillar with coral-red head; full grown, 1¼ inches.	White-marked tussock moth *(Hemerocampa leucostigma)*
June to October, overlapping larval stages	Elm, maple, oak	Solitary. Large green caterpillar, with reddish-brown head; full grown, 3 inches.	Polyphemus moth *(Antheraea polyphemus)*
July to August	Oak (white)	Gregarious when young, solitary later. Jet black caterpillar with orange stripes; full grown, 1¾ inches.	Orange-striped oakworm *(Anisota senatoria)*
July to August	Oak, birch, basswood	Gregarious. Moderately hairy, black caterpillar with four narrow lengthwise pale yellow stripes, yellow-necked; full grown, 2 inches.	Yellow-necked caterpillar *(Datana ministra)*
July to August	Walnut, hickory, butternut	Gregarious. Grayish-black striped caterpillar clothed in long, grayish hairs; full grown, 2 inches.	Walnut caterpillar *(Datana integerrima)*
July to late August	Sugar maple, beech	Solitary; heaviest feeding in upper crown. Yellowish-green smooth caterpillar, with reddish head and a reddish-brown saddle on body; full grown, 1½ inches.	Saddled prominent *(Heterocampa guttivitta)*
July to October, overlapping larval stages	Cherry, boxelder	Solitary. Large bluish-green caterpillar; body with coral-red tubercles; full grown, 3 to 4 inches.	Cecropia moth *(Hyalophora cecropia)*
July to October, overlapping larval stages	Oaks, basswood	Solitary. Yellowish-green smooth caterpillar, with variable reddish markings; full grown, 1½ inches.	Variable oak leaf caterpillar *(Heterocampa manteo)*
July to October, overlapping larval stages	Oak (white)	Gregarious when young, solitary later. Yellow, smooth caterpillar with orange head, *five* black dorsal lines on abdomen and orange-red hump on eighth segment; full grown, 1¾ inches.	Red-humped oakworm *(Symmerista canicosta)*
August to September	Sugar maple	Gregarious when young, solitary later. Yellow, smooth caterpillar with orange head, *three* black dorsal lines on abdomen and orange-red hump on eighth segment; full grown, 1¾ inches.	Orange-humped mapleworm *(Symmerista leucitys)*
Summer	Elm, red maple	Solitary; complete defoliation by gray and brown caterpillars; full grown, 1½ inches.	Elm spanworm *(Ennomos subsignarius)*

Late May to late June	Ash	Solitary. Yellowish- to greenish-white sawfly larva, with brownish head; full grown, ¾ inch.	Brown-headed ash sawfly *(Tomostethus multicinctus)*
Late May to late June	Ash	Solitary. Yellowish- to greenish-white sawfly larva, with shiny black head; full grown, ¾ inch.	Black-headed ash sawfly *(Tethida cordigera)*
Late June to August	Mountain ash	Gregarious. Yellowish sawfly larva with black spots of uneven size and shape; head yellowish orange; full grown, ¾ inch.	Mountain-ash sawfly *(Pristiphora geniculata)*
June to October, overlapping larval stages	Elm, willow	Solitary; usually coiled when not feeding. Pale yellow sawfly larva with longitudinal black stripe and wart-like growths; full grown, 1¾ inches.	Elm sawfly *(Cimbex americana)*
July to October, overlapping larval stages	Willow, aspen	Gregarious. Slate-black sawfly larva, with row of lateral yellow spots; full grown, ¾ inch.	Willow sawfly *(Nematus ventralis)*
August to September	Birch	Gregarious. Yellowish sawfly larva with six rows of black spots on back and a reddish-yellow head; full grown, ¾ inch.	Birch sawfly *(Arge pectoralis)*
BEETLES (COLEOPTERA)			
May to August	Aspen, willow	Shotholes by blackish beetles in the developing leaves. Gregarious larvae skeletonize the lower leaf surface. Full-grown larvae about ⅜ inch long.	Cottonwood leaf beetle *(Chrysomela scripta)*
Spring to early summer	Oak, birch, aspen	Solitary; feeding by adults, not larvae; portions of leaves cut out. Light to dark brown, hard-shelled beetles, ⅜ to 1 inch long.	Leaf chafers — June beetles *(Phyllophaga* spp.*)*
Late June to July	Elm	Solitary; holes chewed in leaves by yellowish-green beetles about ¼ inch long.	Elm leaf beetle *(Galerucella luteola)*
Late spring through summer	Siberian pea	Solitary; feeding by adults, not larvae. Gray, brown, or black soft-bodied beetles, ½ to 1 inch long.	Blister beetles *(Meloidae)*
WALKINGSTICK (ORTHOPTERA)			
Late June to Mid-July	Red oak, basswood, cherry	Trees defoliated by nymphs and adults. Nymphs pale green, darkening to brown at maturity; adults long-legged, wingless; up to 3 inches long.	Walkingstick *(Diapheromera femorata)*

DEFOLIATORS

Injury by defoliators can be classified as: (1) complete or partial destruction of the leaves by free-feeding insects, (2) mining or skeletonizing of the upper or lower leaf surfaces, and (3) leaf rolling, webbing, or tenting of the foliage or branches. Feeding by the free-feeding caterpillars is most noticeable in the later stages of caterpillar development. Under epidemic conditions many thousands of acres of one tree species or of a favorable forest type, even including the underbrush, may be completely denuded. Defoliation being the end result, collection and examination of the feeding insects is necessary for determination of the exact species. The information in table 1 should be sufficient to allow field identification of most of the species in this group. The other types of defoliators, leaf miners, skeletonizers, leaf rollers, web-makers, and tent-makers cause characteristic damage symptoms and are included in the general key.

Free-Feeding Species[1]

Forest Tent Caterpillar

(Malacosoma disstria)

Hosts. — Aspen and sugar maple are the preferred hosts in their forest type areas. Other favored hosts, particularly when growing with aspen and sugar maple, are basswood, oak, cherry, birch, and elm. Red maple is avoided. In outbreak conditions, late-stage caterpillars will feed on brush growth and even garden crops.

Injury. — Heavy feeding causes a decline in vigor, dieback of twigs and branches, and reduction in radial increment. Continued severe defoliation for several years will kill trees on poor sites. Maple sugar orchards may be seriously weakened and the quality and quantity of sap affected. The caterpillars congregate on the trunk or larger branches when at rest or during molts (fig. 1, left) and a silken mat, not a tent, is formed there. Region-wide outbreaks occur at 10- to 15-year intervals.

Description. — The moths are stout bodied and a light buff brown. The wing expanse is about 1½ inches, and the forewings have two dark, oblique lines. When hatched, the caterpillars are black, hairy, and less than a half inch long. As they develop, the hairs disappear and a bluish color becomes evident along the sides of the body. When full-grown they have a row of keyhole spots along the back (fig. 1, right). The egg masses, which encircle the twigs, are cylindrical and have flat ends.

Green-Striped Mapleworm

(Anisota rubicunda)

Hosts. — Red maple is the preferred host in the Lake States; but sugar maple, oak, and boxelder may also be defoliated when the insect population is large.

Injury. — Defoliation over relatively large areas occurs periodically. Little permanent damage has been reported, but heavy feeding causing complete loss of foliage, followed by a partial second-generation feeding on the second crop of leaves, will result in reduction of tree growth.

Decription. — The moths have a yellowish body with the underside pinkish. The wing expanse is 1½

[1] *See item 2 in key and table 1.*

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FIGURE 1. — *Left*, forest tent caterpillars at rest on the trunk and branches of an aspen. *Right*, a full-grown caterpillar; note the keyhole-shaped spots along the back (photo courtesy Quetico-Superior Wilderness Research Center.)

to 2 inches; the forewings are rose colored with a broad yellowish band. The pale yellowish-green, full-grown caterpillar (fig. 2) bears seven dark green or blackish longitudinal lines. There are two long slender horns on the thorax and four prominent dorsal spines at the tail.

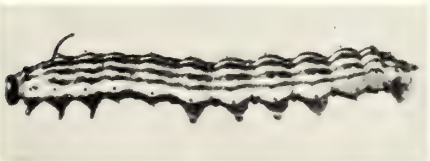

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FIGURE 2. — The green-striped maple-worm; note the prominent stripes and the thoracic horn.

Orange-Striped Oakworm

(Anisota senatoria)

Hosts. — Oaks, especially the white oaks.

Injury. — Although heavy populations are usually confined to local areas, serious defoliation may occur over large acreages; and when this continues for several years, tree vigor is reduced and some trees die.

Description. — The moths are tan or yellowish in general body and wing colorations; the forewings, which have an expanse of about 2 inches, are speckled with black dots and have a large white spot near the middle. The jet-black, full-grown caterpillars (fig. 3) have two longitudinal orange stripes along the back and two similarly colored wavy stripes along the sides. There are a pair of stiff, slender, black spines on the thorax and small, sharp, black spines on the body segments.

Variable Oak Leaf Caterpillar

(Heterocampa manteo)

Hosts. — Oaks are favored. Basswood, beech, birch, and American

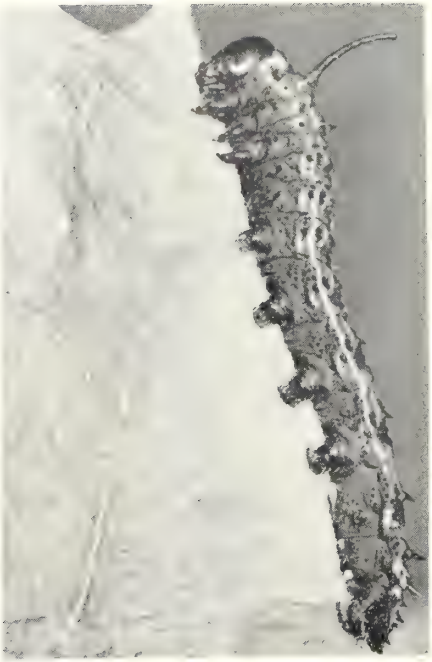

FIGURE 3. — The orange-striped oakworm. Note the various spines. (Photo courtesy of The Connecticut Agricultural Experiment Station.)

elm are frequently defoliated, and other hardwood species are occasionally attacked.

Injury. — The foliage of all sizes of trees is fed on in a characteristic manner (fig. 4, bottom). Occasionally sporadic outbreaks develop, populations increase enormously, and heavy defoliation occurs. Since much of the feeding is late in the season, little damage results unless an infestation persists for several years. When this occurs, tree vigor and growth are affected.

Description. — The moths are ashy gray and have a wing expanse of about 1½ inches. The forewings have three dark, wavy, and diffused lines. Although the general body coloration of the caterpillars is yellowish green, the variable markings (fig. 4, top) — chiefly reddish brown to black and creamy white — are

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FIGURE 4. — *Bottom,* characteristic feeding pattern of the variable oak leaf caterpillar. *Top,* the variable markings on the full-grown caterpillars.

distinctive and serve as a good means for identification.

Saddled Prominent

(Heterocampa guttivitta)

Hosts. — Beech and sugar maple; when abundant it feeds also on many other hardwood species and even on spiraea and blackberry.

Injury. — In the early stages the caterpillars are skeletonizers, but as they develop they eat all but the principal veins. Two consecutive

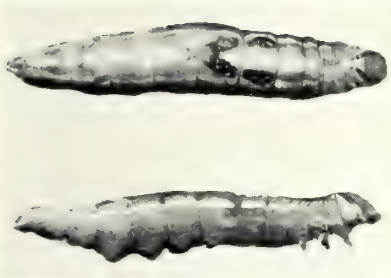

FIGURE 5. — Saddled prominent caterpillars, showing the characteristic saddle. (Photo courtesy of the U.S. Northeastern Forest Experiment Station.)

years of heavy defoliation may kill trees or will kill a large portion of the crowns. When sugar maples are severely defoliated, the quantity and quality of sap and sugar decrease.

Description. — The moths are brownish gray with a wing expanse of about 2 inches; the forewings have indistinct and variable dark crossmarkings. Although the full-grown caterpillars are generally yellowish green, they may vary in color. The reddish-brown saddle (fig. 5) is very prominent — hence the common name.

Yellow-Necked Caterpillar
(Datana ministra)

Hosts. — Oak, birch, basswood.

Injury. — The early stage caterpillars skeletonize the lower leaf surface; as they develop they devour the entire leaf and very often only the stem remains. They feed in large colonies, and as a general rule the greatest damage occurs on small trees.

Description. — The moths are brownish and have a wingspread of about 2 inches. The forewings have numerous irregular, dark hues. The full-grown caterpillars are distinctly striped lengthwise, and the body is sparsely clothed with long, white

FIGURE 6. — A colony of half-grown yellow-necked caterpillars. (Photo courtesy of the Illinois Natural History Survey.)

hairs. The caterpillars are gregarious (fig. 6) and when disturbed they elevate both ends of the body.

Walnut Caterpillar
(Datana integerrima)

Host. — Walnut.

Injury. — The early stage caterpillars skeletonize the lower leaf surface and later consume the entire leaf. Like the yellow-necked caterpillars, they feed in large colonies; and when they are abundant, isolated trees or trees in small groups are subject to heavy feeding. Large groves of trees in forest stands are not so likely to be heavily defoliated.

Description. — The moths are brownish gray and have a wingspread of nearly 2 inches. The forewings are marked by curving, transverse, dark lines. The young caterpillars are red; but when full-

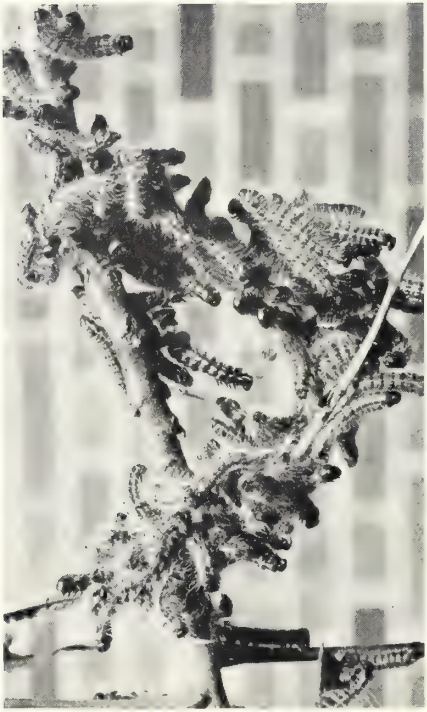

FIGURE 7. — Half-grown walnut caterpillars. Note the grayish-white hairs. (Photo courtesy of the Illinois Natural History Survey.)

grown they are black, indistinctly lined, and covered with numerous long, grayish-white hairs (fig. 7).

Red-Humped Oakworm
(Symmerista canicosta)
Orange-Humped Mapleworm
(Symmerista leucitys)

Hosts. — Oak, chiefly white oak and bur oak; and sugar maple.

Injury. — The early larval stages are gregarious and skeletonize the leaves. As the caterpillars develop, they scatter and consume all but the midribs of leaves. Generally infestations are local, and occasionally the caterpillars are sufficiently numerous to completely defoliate trees.

FIGURE 8. — *Top,* the red-humped oakworm. *Bottom,* pupation in rolled oak leaves. (Photos courtesy of The Connecticut Agricultural Experiment Station.)

Description. — The moths of each species are ash gray with a wing expanse of about 2 inches. The forewings have a whitish streak along the front margin. The full-grown caterpillars are yellowish; the distinguishing characteristic is five black dorsal lines for the oakworm (fig. 8, top) and three black, dorsal lines for the mapleworm. These two species have been confused with the closely related *Symmerista albifrons* but apparently are more northerly in general distribution. Pupation takes place in a rolled leaf (fig. 8, bottom).

White-Marked Tussock Moth
(Hemerocampa leucostigma)

Hosts. — Basswood, elm, aspen, maple. Although a general feeder, it is primarily a pest of shade trees.

Injury. — The early stage caterpillars skeletonize the lower leaf surface; as they develop they eat holes in the leaves and finally devour all but the midrib and main veins.

Description. — The wingless females are hairy, light brown to gray, and about one-half inch long. The male moths are grayish brown to reddish brown and have a wingspread of about 1¼ inches. The full-grown caterpillars can be identified by the coral-red head, two long pencils of black hairs at the front and one at the rear, and a dorsal, white brush or tuft on the first four abdominal segments (fig. 9).

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FIGURE 9. — Caterpillars of the white-marked tussock moth, showing the prominent pencils and tufts.

Gypsy Moth
(Porthetria dispar)

Hosts. — Oak, birch, aspen, and basswood are favored. However, in an outbreak the foliage of most hardwoods and even of some conifers will be eaten. In the Lake States, up to the present time, this insect has been confined to southeastern Michigan. There are large acreages of susceptible forest in the central hardwoods type throughout the north-central region, and there should be constant surveillance for evidence of this pest. It can exist in small numbers in farmwoods or in an extensive stand for some years without causing noticeable defoliation and then suddenly develop to outbreak status.

Injury. — This is an imported insect which, to all intents and purposes, has reached the status of a native insect in that it is subject to periodic increases and decreases in populations. One complete defoliation will not kill trees, but over a period of years, even in thrifty stands, successive defoliations will reduce vigor. When rainfall is deficient during an outbreak, the way

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FIGURE 10. — *Left*, a gypsy moth egg mass covered with hairs from the body of the female moth. *Right*, a full-grown caterpillar.

is opened for attack by secondary insects and tree mortality may be hastened.

Description. — The female moths are nearly white with wavy, black bands across the forewings. Although they have a wing expanse of 2 inches, they are heavy bodied and cannot fly. The male moths are smaller and are dark brown with blackish bands across the forewings. They are slender and, in contrast to the females, are good fliers. The abdomen of the female is covered with yellow hairs that are shed and used to cover the egg mass (fig. 10, left), which is deposited on the bark of trees or under stones and debris on the ground. They are very conspicuous when abundant and can be used in surveys to determine future larval populations. The full-grown hairy caterpillars are about 2 inches long. The dorsal surface of the body, behind the head, has a double row of blue spots on the first five segments and a double row of dark red spots on the next six segments (fig. 10, right).

Spring Cankerworm
(Paleacrita vernata)
Fall Cankerworm
(Alsophila pometaria)
Bruce Spanworm
(Operophtera bruceata)

Hosts. — Elm is probably the preferred host, but birch, maple, and oak may also be heavily defoliated by the cankerworms. Aspen and sugar maple are preferred by the spanworm.

Injury. — The larvae, in the early stages, skeletonize the tender leaves at the branch tips. The older stages eat the leaves partially, but in an outbreak all but the midribs and larger veins may be devoured (fig. 11). As a rule, heavy feeding occurs at intervals of about 15 years and may last for 3 years. Under drought conditions an outbreak may result in reduced tree vigor and radial increment, but forest stands are usually not seriously affected. The early stage Bruce spanworms feed on the blossom buds, and the older stages feed in the same manner as the spring and fall cankerworms.

FIGURE 11. — Feeding damage on elm by the spring cankerworm. (Photo courtesy of the Illinois Natural History Survey.)

Description. — The two cankerworm species are closely associated and look somewhat alike. The female moths are wingless and are about one-third inch long; those of the spring species have a black dorsal stripe, while those of the fall species are uniformly gray. The males of both species are brownish gray, but the fall species is darker. The fall cankerworm lays its eggs in the fall, the spring species in the spring. They hatch about the same time, however, and the caterpillars develop, even on the same branch. Each species varies greatly in coloration and markings, and careful observations are necessary for species separation. The caterpillars of the fall species have three pairs of abdominal prolegs, while those of the spring species have two. The wingless females of the Bruce spanworm are light brownish gray and are about the same length as those of the cankerworms. The male moths are pale grayish with brownish flecks. The full-grown larvae are about one inch long and are bright green with yellowish-white lateral stripes (fig. 12).

Elm Spanworm
(Ennomos subsignarius)

Hosts. — Elm, basswood, red maple, and birch.

Injury. — The feeding damage is similar to that caused by the cankerworms. Large areas, particularly swampland, are periodically heavily defoliated. The caterpillars complete

FIGURE 12. — A full-grown Bruce spanworm. (Photo courtesy of Canada Department of Forestry.)

development in June, and the pupae may be found between leaves spun together or in bark crevices.

Description. — The female moths are white, with a wing expanse of about 1½ inches; they are also called snow-white linden moths. Unlike the moths of the cankerworms, they are winged. The full-grown caterpillars are about 1½ inches long and are gray and brown in general color with irregular markings. They closely resemble elm twigs.

Linden Looper

(Erranis tiliaria)

Hosts. — Basswood and elm are preferred; but oak, birch, maple, and other hardwoods are attacked when the insect is abundant.

Injury. — Typically the feeding damage is similar to that caused by the spring and fall cankerworms in that the individual leaves are partially eaten. When an outbreak occurs, almost all the foliage is destroyed. Usually, however, such conditions are local and short-lived and are reduced in intensity by weather and other factors.

Description. — The wingless females are about one-half inch long and vary in color from brown to gray with two rows of black dorsal spots. The male moths are buff colored and have a wingspread of nearly 2 inches. The bright yellow caterpillars (inchworms or loopers) have 10 wavy, black lines along the back, with the outer one on each side heavier.

Cecropia Moth

(Hyalophora cecropia)

Hosts. — Cherry and boxelder, chiefly in the Northern Great Plains.

Injury. — Sometimes called giant silkworms, the caterpillars are solitary feeders. Generally they occur singly or in small numbers. By the late stages the feeding injury is more noticeable than injurious, but it is sometimes serious in shelterbelt plantings. There are overlapping larval stages so that defoliation may be noticeable from July to October.

Description. — The moths are brownish with rusty-red and grayish-white markings and a wingspread of 5 to 6 inches. There is a conspicuous crescent - shaped, white spot near the center of all four wings and also a white crossband bordered with red. The full-grown caterpillars, often 4 inches long and a half inch or more in diameter, are very conspicuous, the body bearing four coral-red, dorsal tubercles on the thorax and 15 dorsal, yellow tubercles on the abdomen (fig. 13).

FIGURE 13. — A cecropia caterpillar. Note the various tubercles. (Photo courtesy of the U.S. Northeastern Forest Experiment Station.)

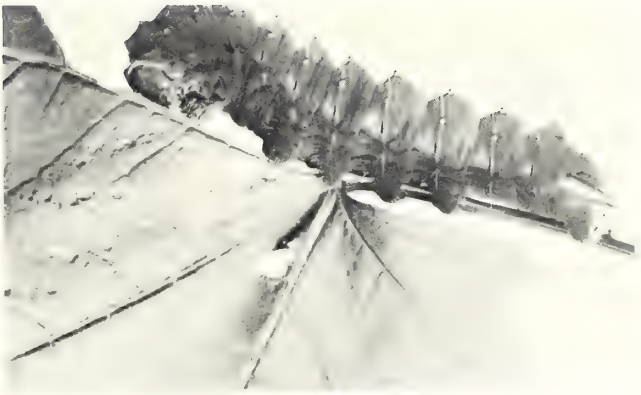


FIGURE 14. — A polyphemus caterpillar; the orange - to - reddish tubercles are conspicuous. (Photo courtesy of The Connecticut Agricultural Experiment Station.)

Polyphemus Moth
(Antheraea polyphemus)

Hosts. — Elms, maples, and oaks, chiefly in the Northern Great Plains.

Injury. — This is another of the giant silkworms; its feeding habits are similar to those of the cecropia moth. Overlapping larval stages result in noticeable defoliation from June to October.

Description. — The moths are brownish yellow with a wing expanse of 4 to 6 inches. There is a transparent eyespot on each wing, those on the hind wings having a dark border. The full-grown caterpillars are often 3 inches long and a half inch in diameter. They are ornamented with small, orange-to-reddish tubercles from which rise one to three straw-colored bristles (fig. 14). The last body segment bears a V-shaped, purplish design.

Mourning-Cloak Butterfly (Spiny Elm Caterpillar)
(Nymphalis antiopa)

Hosts. — Elms, aspens, willow, and hackberry.

Injury. — The caterpillars feed in colonies, eating all of the leaf tissue but the larger veins. They are more frequently found in the upper portion of the tree, and whole branches may be defoliated. There are two generations annually, but the defoliation by the first generation is the more noticeable.

Description. — The moths are deep brownish purple, with the outer edges of the wings banded with creamy yellow; inside these bands is a row of blue spots. The wing expanse is from 2 to 3 inches. The full-grown caterpillar is black with white raised dots and a conspicuous row of red spots down the middle of the back. Each body segment has a transverse row of black branched spines (fig. 15).

Birch Sawfly
(Arge pectoralis)

Host. — Paper birch.

Injury. — Trees are partially or wholly defoliated during August and September. The larvae are gregarious and cling to the edge of the leaves while feeding. When abundant, they may defoliate trees heavily over relatively large areas.

Description. — The adults are about three-eighths inch long, with semi-membranous wings. The most characteristic feature of the adults is the three-segmented antennae. The full-grown larvae (fig. 16) are about three-fourths inch long; they are yellowish with six rows of conspicuous black spots down the back and have reddish-yellow heads.

FIGURE 15. — Spiny elm caterpillars (of the mourning-cloak butterfly). (Photo courtesy of The Connecticut Agricultural Experiment Station.)

Elm Sawfly
(Cimbex americana)

Hosts. — Elm, willow, and occasionally basswood, birch, maple, and aspen.

Injury. — The leaves may be partially or wholly devoured, even the veins, by the larvae. The adults emerge from late May to August, so that larvae may be found until October. The adults sometimes chew the thin, tender bark of twigs, girdling and killing them and causing noticeable crown injury. This insect is not common in the forest, but is more important as a shade-tree pest.

Description. — The adult females are among the largest of our sawflies, ranging from ¾ to 1 inch long. Their robust bodies are steel blue with oval yellow spots on each side. The semitransparent wings are smoky brown in general color, and the wingspread is about 2 inches. The black dorsal line on the pale yellowish-green larvae is an excellent means of recognition. When at rest, they coil up, like snails, around a twig (fig. 17).

Brown-Headed Ash Sawfly
(Tomostethus multicinctus)
Black-Headed Ash Sawfly
(Tethida cordigera)

Hosts. — Ash.

Injury. — Feeding from the undersurface, the early stage larvae eat shotholes in the leaflets. When the larvae are abundant, the later stages devour the leaflets completely — often leaving only the main stem of the compound leaf.

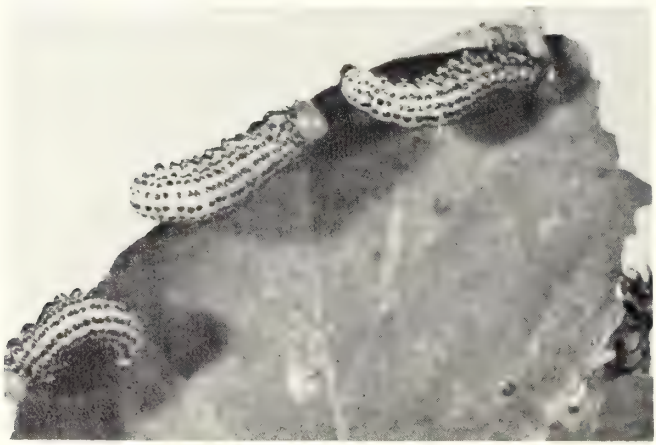


FIGURE 16. — Larvae of the birch sawfly. (Photo by D. C. Anderson, courtesy Canada Department of Forestry.)

FIGURE 17. — An elm sawfly larva, much enlarged, in the typical coiled-up position. (Photo courtesy of The Connecticut Agricultural Experiment Station.)

Description. — The adults of the two species look much alike and range from ¼ to ⅜ inch long. They are black and have semi-membranous wings (fig. 18). The larvae are also very similar; as their common names imply, the species can be separated by the color of their heads — brown or black.

Willow Sawfly
(Nematus ventralis)

Hosts. — Willow and aspen.

Injury. — The early stage larvae feed in compact colonies, making small holes in the leaves. As they develop, each leaf except the midrib is eaten. The most severe damage occurs on willow along streambanks, but aspen will also be attacked.

Description. — The sawflies are brownish black with yellowish-white markings. They are about one-third inch long and have membranous wings with a spread of about half an inch. The developing larvae are greenish black with a row of large yellow spots on each side of the body; when full grown, the general body color is slate black, and the spots are somewhat faded. They rear back when disturbed (fig. 19).

Mountain-Ash Sawfly
(Pristiphora geniculata)

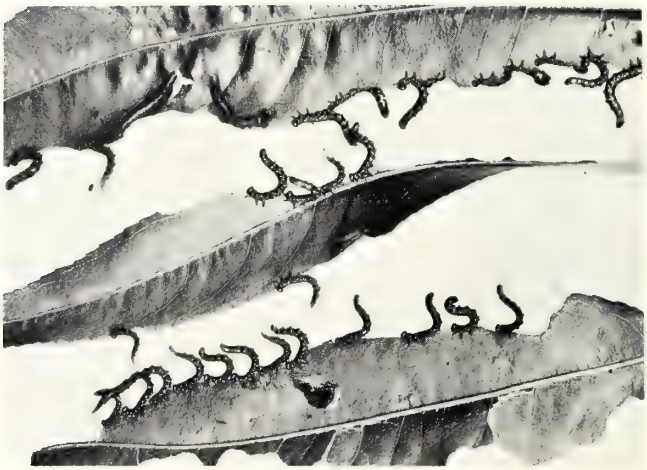
Host. — Mountain ash.

Injury. — The early stage larvae skeletonize the leaves between the veins; as they develop they devour all but the midrib. This species feeds in colonies, usually eating all the leaves on one small branch before moving to another branch. Scattered trees in a forest stand are as subject to defoliation as ornamental trees.

Description. — The sawflies are stout and shiny black, and vary from 3/16 to 5/16 inch in length, the males being smaller than the females. The full-grown larvae are yellow, with numerous black spots on the body segments, and are about ¾ inch long (fig. 20).

F-504122

FIGURE 18. — The brown-headed ash sawfly; 1, adult female; 2, adult male; 3, larvae.



F-504085
FIGURE 19. — Larvae of the willow sawfly, showing the typical rearing back when disturbed.

FIGURE 20. — Full-grown larvae of the mountain-ash sawfly. (Photo by D. C. Anderson, courtesy of Canada Department of Forestry.)

Walkingstick
(Diapheromera femorata)

Hosts. — Oaks of the red oak group, basswood, and cherry are the preferred hosts. Other hardwoods growing with these hosts may also be attacked.

Injury. — Defoliation is especially noticeable where the favored hosts are concentrated. Two years are required for development, and there are even-year and odd-year broods in various parts of the region. Unless both broods are present in a particular locality, defoliation will occur in alternate years. These insects are wingless and lateral spread is slow.

Description. — Development occurs through incomplete metamorphosis, there being no change in body form as in pupation. In the early stages the nymphs are greenish; as they develop they change to dark green, gray, or brown. When full grown, the walkingsticks measure up to 3 inches in length, the females being larger than the males (fig. 21).

June Beetles (Leaf Chafers)
(Phyllophaga spp. particularly)

Hosts. — All the common hardwoods and shrubs around nurseries and fields and in woodlots and shelterbelts. Among the tree species the oaks, birches, and aspens are preferred.

F-504094
FIGURE 21. — Male (smaller) and female walkingsticks.

Injury. — While damage to coniferous seedlings and transplants by the larvae (white grubs) is the more important type of injury, that caused by adults feeding on the foliage of forest trees may also be serious. The heaviest damage occurs in the spring when the leaves are tender. Much of the feeding is at night. When beetle populations are high, this feeding damage may be very noticeable. Although the genus *Phyllophaga* is considered the most important, other genera are involved and the generic feeding patterns are distinct. In some cases the leaves are eaten across the main veins at the tip; in others circular or oval holes are eaten out of the margins; and in still others holes are eaten inside the margins and between the veins. Where heavy feeding occurs, pieces of the leaves can usually be found on the forest floor below the feeding area. This is in contrast to feeding by insects such as the forest tent caterpillar, which can be identified by the presence of frass on the leaves or on the forest floor.

Description. — The robust beetles are ½ to 1 inch long and vary in color from light brown through dark brown to brownish black. They have powerful biting jaws (mandibles), which are used in cutting the leaves. In a typical feeding position the legs on one side of the body are on the upper surface of the leaf and those on the other side are on the lower surface, with the edge of the leaf between the mandibles (fig. 22).

Blister Beetles
(Meloidae)

Hosts. — Shrubs and young hardwoods in nurseries, ornamental plantings, and shelterbelts.

F-506528
FIGURE 22. — Typical feeding damage on paper birch foliage by a June beetle.

F-500803
FIGURE 23. — A blister beetle feeding on the leaves of the Siberian pea shrub.

Injury. — Although the leaves, as a rule, are partially eaten at the margins, heavy populations will cause noticeable defoliation, particularly on windbreaks in nursery areas.

Description. — The adults are ½ to 1 inch long and vary in color, generally being gray or black (fig. 23). The abdomen often is large and extends beyond the ends of the wingcovers. The larvae of some species are predatory on grasshopper eggs in the soil.

Webworms, Tent-Makers, Leaf Rollers

Eastern Tent Caterpillar (See Key, 12)
(Malacosoma americanum)

Prairie Tent Caterpillar (See Key, 13)
(Malacosoma lutescens)

Host. — Cherry.

Injury. — Defoliation of branches and, under outbreak conditions, of entire trees. Tents are spun in the branch forks during May and June (fig. 24); they are used chiefly as resting places, and the caterpillars move out to feed on the nearby foliage. This insect is often confused with the forest tent caterpillar; however, the latter does not spin a tent and the preferred hosts are aspen and sugar maple.

Description. — The moths are dull reddish brown with a wingspread of 1½ to 2 inches. The forewings have two nearly parallel oblique white bars. The full-grown caterpillars are 2 inches long, and are deep black in general body color

F-404155
FIGURE 24. — The tent of the eastern tent caterpillar on black cherry.

with a rather broad white dorsal stripe. The egg masses, cemented on small twigs, form a dark oval mass rounded at the ends and usually only partially surround the twig. Those of the forest tent caterpillar are deposited in the same manner, but are flat at the ends and completely encircle the twigs. The closely related prairie tent caterpillar is of importance on chokecherry in shelterbelt areas. The tents are somewhat similar to those made by the eastern tent caterpillar. The full-grown caterpillars are brown, with a row of elliptical blue spots down the center and two orange spots on each segment. The sides have pale orange lines and spots.

Fall Webworm (See Key, 13)
(Hyphantria cunea)

Hosts. — Elm, ash, aspen, cherry, and willow are the preferred forest species in the Lake States.

Injury. — The caterpillars feed in colonies in conspicuous webs, which usually enclose all the foliage on one limb (fig. 25). When the insect is very abundant an entire tree may be enclosed. In the early stages, the caterpillars skeletonize the leaves; as they develop, all but the midribs are eaten. In the southern and warmer part of the Lake States there may be two generations; in the north there is one. The tents in the first generation are often confused with those of the tent caterpillars, which are formed only in the forks of limbs and branches.

F-505763

FIGURE 25. — Defoliation and the webbing caused by the fall webworm.

Description. — The moths vary in color from pure white to white with black or brown spots on the wings; the wing expanse is about 1¼ inches. The full-grown caterpillars are about 1 inch long. There is considerable color variation, but generally they are pale yellow or green with a broad dark stripe down the back and a yellow lateral stripe. The body is covered with gray or red hairs which arise from black and orange warts.

Oak Webworm (See Key, 13)
(Archips fervidanus)

Hosts. — Red, black, and scarlet oaks.

Injury. — The caterpillars are gregarious and feed on the foliage of sprout growth and seedlings in webs often a foot to a foot and a half long and several inches in diameter (fig. 26). These webs may enclose all the foliage at the tips of branches or at the tops of the trees. They are noticeable by late June.

Description. — The moths are brownish with a wing expanse of about three-fourths inch and with darker patches on the light-brown forewings. The full-grown caterpillars are black headed, gray green in body color, and about three-fourths inch long.

Ugly-Nest Caterpillar (See Key, 13)
(Archips cerasivoranus)

Hosts. — Chokecherry and black cherry.

F-504083
FIGURE 26. — A mass of leaves webbed together by the oak webworm.

Injury. — The caterpillars are gregarious and construct a web, tying the twigs and leaves into a dense nest and enlarging it as they feed on the foliage. Individual nests may be a foot or more long (fig. 27). Under heavy population conditions the nests may be numerous and an entire small tree may be enclosed.

Description. — The moths are dull orange, with a wing expanse of about 1 inch and reddish-brown speckling on the forewings. The full-grown caterpillars are about three-fourths inch long, black headed, and yellow bodied. Pupation occurs within the web, and prior to moth emergence the pupae wriggle part of the way out of the nest. The cast pupal skins remain attached to the nest and are a good indication that feeding has been completed.

FIGURE 27. — Nest of the ugly-nest caterpillar on pin cherry. (Photo courtesy of the U.S. Northeastern Forest Experiment Station.)

Maple Leaf Rollers (See Key, 14)
(Sparganothis acerivorana)
(Acleris chalybeana)

Maple Webworm (See Key, 13)
(Tetralopha asperatella)

Hosts. — Sugar maple, red maple, and silver maple; and sometimes aspen, beech, and oak.

Injury. — A few years ago a startling amount of mortality of sugar maple appeared in northern Wisconsin. All sizes of trees died — from small saplings to mature trees. Although the causes leading up to this condition are not completely known, it has been established that a complex of defoliating insects, each species hitherto considered of minor importance, was the major cause. The insect injury appeared as leaf rolling and webbing from mid-May to mid-August. The caterpillars of *Sparganothis acerivorana* appear in May as solitary feeders, rolling the leaves and using them as resting places from which they move out to feed on adjacent leaves (fig. 28, top). The caterpillars of *Acleris chalybeana*, also solitary feeders, attract attention in June, rolling some leaves and feeding in them but also in those already rolled by the first species. The webworms are the last to be apparent; gregarious, they feed in the leaves rolled by the leaf rollers, skeletonizing the inner surface (fig. 28, bottom). After a brief period they web groups of leaves and feed on them, sometimes enclosing a whole branch. These webworms, appearing late in the season, were responsible for the major portion of the damage in the northern Wisconsin outbreak, by reducing the amount of stored food necessary for adequate early tree growth the next season.

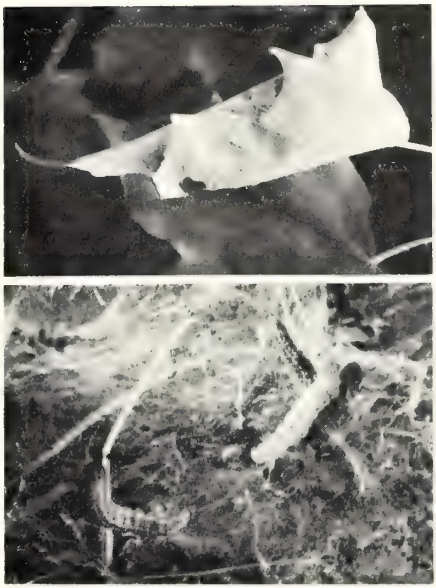


FIGURE 28. — *Top*, leaf rolled by a maple leaf roller. *Bottom*, larvae of the maple webworm in a web. (Photos courtesy of the University of Wisconsin.)

Description:
Sparganothis acerivorana: The moths are reddish yellow with reddish brown spots, and with a wingspread of about 1 inch. The full-grown caterpillars are yellowish green with a tan head and are about 1 inch long.

Acleris chalybeana: The moths are grayish and have a wingspread of about seven-eighths inch. The full-grown caterpillars are light green and are about seven-eighths inch long.

Tetralopha asperatella: The moths are powdery gray and have a wingspread of nearly 1 inch. The full-grown caterpillars vary in color from yellow to green and brown to nearly black. They are about three-fourths inch long.

Fruit-Tree Leaf Roller (See Key, 14)
(Archips argyrospilus)

Hosts. — Oak, elm, aspen, ash, and soft maple.

Injury. — The early stage caterpillars feed on the swelling buds

FIGURE 29. — The leaf rolling habit of the fruit-tree leaf roller. (Photo courtesy of the Canada Department of Agriculture.)

in May, injuring the terminal growth. Later they feed on the unfolding leaves, rolling and webbing them (fig. 29). When there are large populations, the terminal growth suffers considerable damage.

Description. — The moths are brownish. The wingspread is about seven-eighths inch, and the forewings have a creamy or straw-colored mottling. The full-grown caterpillar is about three-fourths inch long, and has a light-green body and a dark-brown or black head.

Large Aspen Tortrix (See Key, 14)
(Choristoneura conflictana)

Host. — Aspen.

Injury. — The gregarious, first-instar caterpillars web two leaves together in July and August and skeletonize the touching surfaces. They hibernate as second-instar larvae in sheltered places such as bark crevices or under loose bark. Activity is resumed in the spring and, as solitary feeders, they bore into the buds and feed on the tissues of the expanding leaves. As the caterpillars develop, the leaves are rolled and whole portions are eaten. When the insects are abundant, heavy defoliation occurs. Pupation takes places in the rolled leaves (fig. 30). The moths emerge in late June.

Description. — The moths are light gray and have a wing expanse of 1 to 1¼ inches with darker patches on the forewings. The full-grown caterpillars are about seven-eighths inch long and are dark green to almost black in general body color.

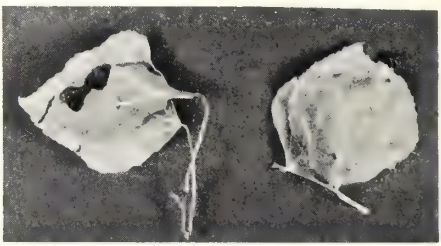


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FIGURE 30. — Large aspen tortrix pupae in rolled leaves.

Aspen Leaf Roller (See Key, 14)
(Anacampsis innocuella)

Hosts. — Aspens.

Injury. — The solitary-feeding caterpillars roll the leaves, the injury becoming noticeable in the

FIGURE 31. — The aspen leaf roller. (Photo courtesy of the Ohio Agricultural Experiment Station.)

upper crown about the middle of May. Early in the season single leaves are rolled (fig. 31); later two or more leaves may be rolled together. Early stage larvae may damage the opening buds. When nearly full grown, the larvae sever the petioles and the leaves drop to the ground where feeding and development are completed.

Description.—The moths are ashy gray with a wing expanse of about seven-eighths inch. The full-grown larvae are about five-eighths inch long and have a dark-brown head. They are translucent, and the green food shows through the body wall.

Basswood Leaf Roller (See Key, 14)
(Pantographa limata)

Host. — Basswood.

Injury. — The apical half of each leaf is rolled into a tube where the caterpillar feeds and develops (fig. 32). This feeding occurs during the

FIGURE 32. — A basswood leaf rolled by the basswood leaf roller. (Photo courtesy of the U.S. Northeastern Forest Experiment Station.)

latter part of the summer; and even though the insect is often abundant, complete defoliation seldom occurs and damage is of little consequence.

Description. — The moths have a wingspread of more than 1 inch and are pale yellowish white with olive or brown markings. The full-grown caterpillars are bright green and about 1 inch long.

Leaf Miners and Skeletonizers

Aspen Leaf Miner (See Key, 14)
(Phyllocnistis populiella)

Hosts. — Aspens.

Injury. — The larvae are sap-feeding leaf miners; their meandering mines on the under leaf surface appear as small tracks (fig. 33). Forest trees are not seriously damaged, but attacked leaves on ornamental trees are conspicuous and sometimes cause concern.

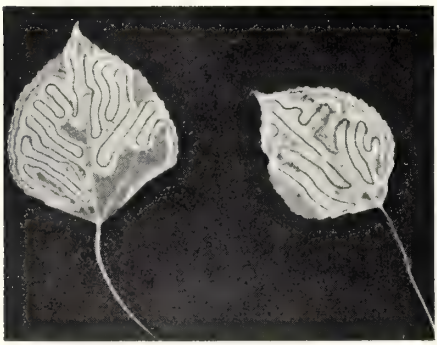

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FIGURE 33. — The small-track mine made by the aspen leaf miner.

Description. — The moths are silvery white and have a wingspread of about one-quarter inch. The larvae are flat in the early instars but become cylindrical when mature. They are white to light cream, and when full-grown are less than one-quarter inch long.

Aspen Blotch Miner (See Key, 14)
(Lithocolletis tremuloidiella)

Host. — Aspen.

Injury. — Irregularly shaped blotchy tentlike mines are made in the leaves in June and early July and again in August. The mines may be nearly three-fourths inch long and half as wide, and several may develop in each leaf. They are somewhat similar to those made by the solitary oak leaf miner but the individual mines are not so distinct. The upper surface of the mines is paler than the surrounding areas. The heaviest attack is on young trees or in the lower crown of larger trees. Forest trees usually are not seriously affected, but heavy feeding will cause premature dropping of the foliage.

Description. — The moths are white with brown bands across the forewings. The wingspread is about one-quarter inch. The full-grown caterpillars are dark and about one-fifth inch long.

Solitary Oak Leaf Miner (See Key, 14)
(Cameraria hamadryadella)
Gregarious Oak Leaf Miner
(Cameraria cincinnatiella)
(See Key, 14)

Hosts. — Oaks, chiefly in the white oak group.

Injury. — Irregular white blotchy mines just below the upper leaf surface. Although the larvae are solitary feeders, each leaf may have several contiguous mines (fig. 34). The mines are very conspicuous on the foliage of ornamental trees when the insects are abundant, but they are of minor economic importance in the forest. Generally there are two generations of this leaf

F-504082
FIGURE 34. — Oak leaves with the blotchy mines characteristic of attack by the solitary oak leaf miner.

miner annually. The closely related gregarious oak leaf miner causes the same type of injury, but several larvae will feed together in a large brownish-yellow mine; when there are several mines in a leaf, much of the leaf tissue will be destroyed.

Description. — The tiny moths have long, slender, pale forewings with bronze patches; the wing expanse is about one-fourth inch. The larvae are flat and dark yellow; when mature, they are about one-fifth inch long.

Birch Skeletonizer (See Key, 14)
(Bucculatrix canadensisella)

Oak Skeletonizer (See Key, 14)
(Bucculatrix ainsliella)

Hosts. — Paper birch and yellow birch; red oak and black oak.

Injury. — The early larval stages form meandering mines in the leaves (fig. 35, left), and the older larvae skeletonize the lower surface, leaving the upper surface intact. Small flat molting webs are evidence of the presence of larvae. Heavy infestations by the birch skeletonizer result in complete defoliation, but as the greater part of the feeding occurs late in the season growth reduction is not serious. Foliage browning by the oak skeletonizer (fig. 35, right) occurs earlier and heavy feeding will cause some loss of growth.

Description. — The tiny moths of the birch skeletonizer are brown and white; the forewings are brownish with diagonal white bars. The wingspread is about five-sixteenths inch. The moths of the oak skeletonizer are creamy white and are about the same size as the birch species; the forewings have a brown longitudinal band and a purplish-brown spot at the middle of the inner margin. The full-grown larvae of both species are yellowish green and about one-fourth inch long.

Birch Leaf Miner (See Key, 14)
(Fenusa pusilla)

Hosts. — Paper birch, yellow birch, and European white birch.

Injury. — Grayish, discolored, blotchy areas between the upper and lower leaf surfaces. The attacked areas wrinkle and turn

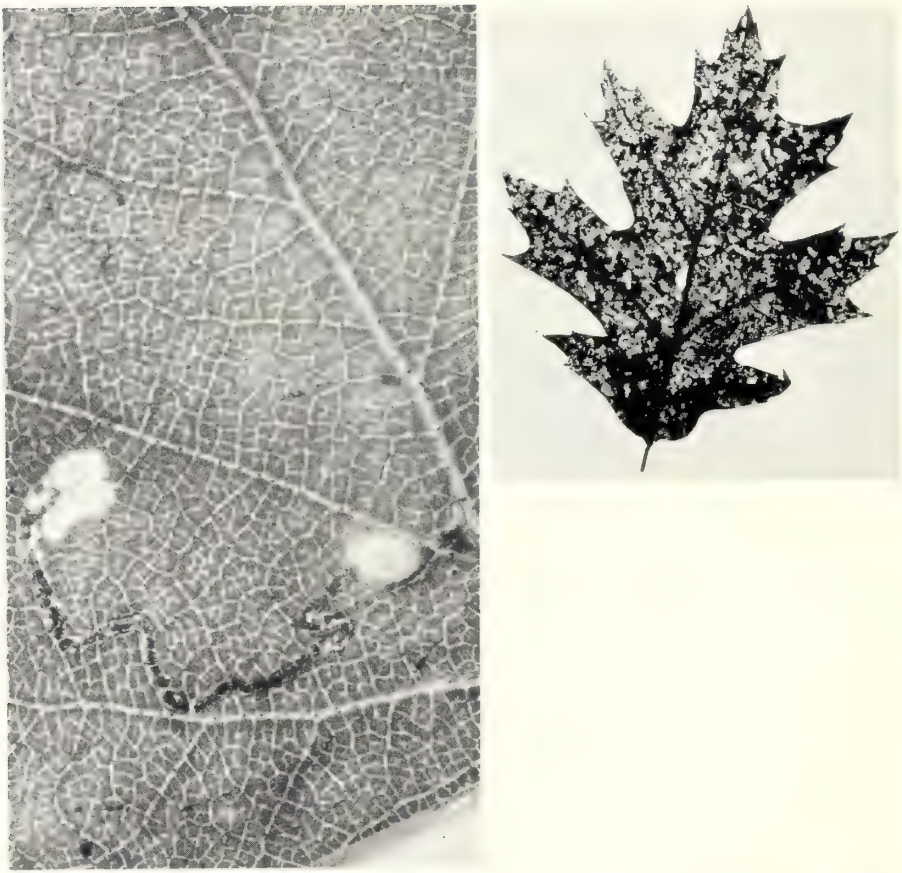

FIGURE 35. — *Left*, a meandering mine made by the birch skeletonizer. (Photo courtesy of The Connecticut Agricultural Experiment Station.) *Right*, an oak leaf mined by the oak skeletonizer. (Photo courtesy of the U.S. Northeastern Forest Experiment Station.)

brown (fig. 36). The heaviest feeding is generally in the tender new leaves at the tops of the trees or the ends of the branches. There may be two or three generations annually.

Description. — The adults are black sawflies about one-fourth inch long with semi-membranous wings. The full-grown larvae are pale green or white, with black spots on the lower side of the thorax and first abdominal segment.

Elm Leaf Miner (See Key, 14)
(Fenusa ulmi)

Hosts. — English and Scotch elms, occasionally American elm. This insect is an introduction from Europe.

Injury. — Large blotchy or blisterlike larval mines are formed between the upper and lower leaf surfaces (fig. 37) in late May and early June. Several larvae may be in one common mine. There is one generation annually. Small trees are most seriously injured, but large trees may also be heavily infested.

FIGURE 36. — Leaves mined by the birch leaf miner. (Photo courtesy of The Connecticut Agricultural Experiment Station.)

In severe infestations the leaves fall prematurely.

Description. — The adults are sawflies, very similar in appearance to those of the birch leaf miner. The legless, flattened larvae are white with a greenish cast and have a brown head.

Locust Leaf Miner (See Key, 14)
(Xenochalepus dorsalis)

Host. — Black locust.

Injury. — Blisterlike spots or brown patches and holes on the leaves. The early stage larvae feed as a colony on a single mine; but

FIGURE 37. — Leaves mined by the elm leaf miner. (Photo courtesy of The Connecticut Agricultural Experiment Station.)

later they mine individually, and there will be several mines in a single leaf (fig. 38). There are two generations; and when populations are high, there will be premature leaf fall, allowing for refoliation. Although the early feeding is more serious, that on the second crop of leaves is also important, as the stored food necessary for the next season's growth may be seriously depleted. In heavy infestations, large areas are brown as if burned. Although the feeding injury by the larvae is the more important, some damage is caused by the beetles as they skeletonize the lower surface of the leaves or chew small holes in them.

Description. — The adults are small flat beetles, about one-fourth inch long and orange red in general color; heads, antennae, and legs are black. The black inner edge of each wing cover forms a dorsal stripe when the wings are closed. The full-grown larvae are yellowish white with black heads and are about one-fourth inch long.

FIGURE 38. — Locust leaf (much enlarged) mined by the locust leaf miner. (Photo courtesy of Pennsylvania State University.)

Basswood Leaf Miner (See Key, 14)
(Baliosus ruber)

Hosts. — Basswood and oak.

Injury. — The adults skeletonize the leaves, usually the upper surface, in late May and early June. When abundant, complete browning may result. The young adults also skeletonize the leaves in the fall. The larvae mine the leaves in June and July; often several may be in one common mine (fig. 39). This is the more conspicuous evidence of injury, and it is usually more serious than that caused by the adults. Following heavy feeding for 2 or 3 years, the tree crowns become thin and dead branches are common, but few trees die.

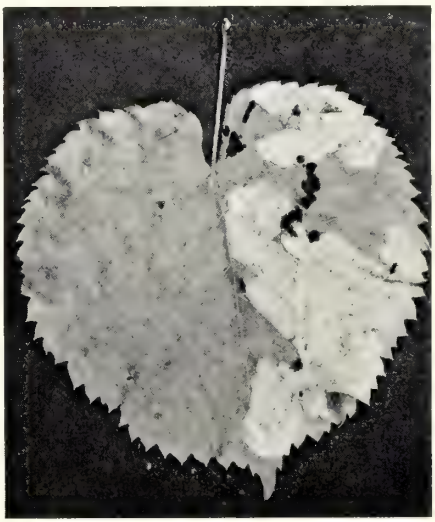

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FIGURE 39. — A leaf mined by the basswood leaf miner.

Description. — The adults are broad, wedge-shaped, reddish-yellow

beetles about one-fourth inch long. The full-grown larvae are also about one-fourth inch long; their general body color is white and the head and thorax are brownish red.

Cottonwood Leaf Beetle (See Key, 14)
(Chrysomela scripta)

Hosts. — Aspens and willows.

Injury. — The adults appear early in the spring and chew holes in the developing leaves and also chew the tender bark at the branch tips. The gregarious larvae skeletonize the lower leaf surface (fig. 40). When the insects are abundant, young saplings may be completely defoliated. Depending on weather conditions, there will be two or three generations annually.

Description. — The hard-shelled beetles, which are about one-third inch long, have a black head and thorax. The wingcovers are generally yellow with black interrupted stripes, although they may be almost black. The young larvae are black and when full-grown are a dirty yellow and about three-eighths inch long.

F-500797

FIGURE 40. — Cluster of leaf beetle larvae feeding on an aspen leaf.

Cottonwood Leaf-Mining Beetle (See Key, 14)
(Zeugophora scutellaris)

Hosts. — Aspens, chiefly cottonwood.

Injury. — Often abundant in riverbottoms in shelterbelt areas, the adults skeletonize the lower surface of the young leaves in May. The larvae feed just below the upper leaf surface in June; they are solitary feeders, but there may be several separated mines in a leaf. The lower layers of spongy leaf tissue turn black, and heavy feeding makes this appear as large, black blisters. When the insects are abundant, complete defoliation may occur over relatively large areas. The damage appears similar to that caused by cottonwood leaf beetles.

Description. — The beetles are about one-eighth inch long; the wingcovers and the abdomen are black and the remainder of the body is yellow. The yellowish-green larvae are flat, and they have characteristic black markings on the dorsal and ventral surfaces. When full grown, they are about three-sixteenths inch long.

Elm Leaf Beetle (See Key, 14)
(Galerucella luteola)

Host. — Elm.

Injury. — Damage in forested areas is not usually serious; shade and ornamental trees may be repeatedly defoliated, making them subject to attack by bark beetles, borers, and diseases. The adults eat holes in the leaves; but by far the more serious damage is the skeletonization of the foliage by the

FIGURE 41 — Elm leaf beetle larvae skeletonizing elm leaves. (Photo courtesy of the U.S. Northeastern Forest Experiment Station.)

larvae (fig. 41), causing the leaves to dry up and fall prematurely. Although there are two generations in the southern part of the Lake States, the first one causes the major portion of the damage.

Description. — The adults are about one-fourth inch long, yellowish green to olive green with a black stripe along the outer margin of the wing covers. The early stage larvae appear to be nearly black; when full grown, they are about one-half inch long and are dull yellow with two black dorsal stripes.

GALL MAKERS

Galls are formed on the foliage or woody portions of a tree as a result of the feeding activities of certain aphids, mites, gall wasps, and wood borers. The leaves in particular are subject to attack by a relatively large number of insects and mites which cause the development of leaf galls. Larvae of certain wood-boring beetles also cause galls, but the main damage is from their tunneling and subsequent breakage of twigs, branches, and stems of sapling trees.

Galls formed by these pests — especially leaf galls — are frequently very striking. A specific pest can often be identified by the bizarre shape and color of the gall which develops around it. In spite of appearances, little real damage is caused by these galls in most cases. Affected leaves are often able to carry out photosynthesis in a near-normal manner. In contrast, some of the less striking twig and branch galls can kill a significant portion of the crown, and a general decline of tree vigor follows.

Psyllids

Hackberry Nipple Gall (See Key, 20)
(Pachypsylla celtidismamma)

Host. — Hackberry.

Injury. — Conspicuous galls on the undersurface of the leaves. When abundant, they seriously deform the leaves and may cause early leaf fall.

Description. — The nipplelike gall is light green and about one-sixth inch in diameter (fig. 42). It forms on the under leaf surface and causes depressions on the upper leaf surface. The nymphs, which inhabit the galls, are pale yellowish green with red eyes. The adults are small, jumping plant lice.

FIGURE 42. — The hackberry nipple gall. (Photo courtesy Illinois Natural History Survey.)

Aphids

Poplar Vagabond Aphid (See Key, 22)
(Mordwilkoja vagabunda)

Hosts. — Quaking aspen and cottonwood.

Injury. — Peculiarly curled and twisted masses of foliage up to 2 inches in diameter at the tips of the twigs (fig. 43). Early in the summer the injury appears as shiny-green, thin-skinned hollow galls, As they mature they change color through dark brown to black. They hang on the twigs during the winter, causing an unsightly appearance.

F-506747
FIGURE 43. — A vagabond aphid gall on quaking aspen.

Description. — Each gall contains a single wingless aphid, the parent of a generation which feeds on an unknown alternate host. The aphids leave the galls in midsummer, but return to them in the fall to hibernate. This habit results in reinfestation of some trees year after year, whereas trees nearby seem to be immune.

Poplar Petiole Gall Aphids (See Key, 23)

(Pemphigus populicaulis)
(Pemphigus populi-globuli)
(Pemphigus populi-transversus)

Hosts. — Aspens.

Injury. — The first two species form galls at the junction of the petioles and the leaves; the third species forms them near the middle of the petioles. They are of little importance in the forest, but may damage some shelterbelt or shade trees. Sometimes attacked leaves drop prematurely and the crowns of heavily infested trees may appear to be thin.

Description. — The galls look somewhat like those caused by the aspen gall moth (discussed below), but they are semiglobular and sometimes cone-shaped. There is a mouthlike orifice and the interior of each gall is crowded with small plant lice (aphids) feeding on the succulent walls. The mealy white powder and globules of honey dew distinguish these galls from those of the aspen gall moth.

Moths

Aspen Petiole Gall Moth (See Key, 23)

(Ectoedemia populella)

Hosts. — Aspens.

Injury. — Formation of galls on the petioles at the junction with the leaves (fig. 44). When heavy attacks occur, early leaf fall may be an important problem, particularly in shelterbelt plantings or on shade and ornamental trees.

Description. — The globular galls, usually the same color as the peti-

FIGURE 44. — Petiole galls caused by the aspen petiole gall moth. (Photo courtesy U.S. Northeastern Forest Experiment Station.)

oles and about the size of a large pea, measure up to three-eighths inch in diameter. They are caused by small, slightly flattened caterpillars. So far as is known there is one generation annually.

Mites

Ash Flower-Gall Mite (See Key, 21)
(Eriophyes fraxiniflora)

Hosts. — White ash.

Injury. — Masses of irregular fringed galls, often 2 inches or more in diameter at the tips of the flower-bearing twigs. These masses are formed by numerous lobed galls which may be as much as a half-inch in diameter. Trees are not killed but their unsightly appearance makes this insect an important shade and ornamental tree pest.

Description. — The galls result from the feeding activity of small mites in the staminate flower clusters. When first formed, the galls are greenish; by midsummer they turn dark brown or black and remain on the twigs over the winter in a dried-up condition (fig. 45).

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FIGURE 45. — An old, dry ash flower-gall at the lower right. At the top are newly infested staminate flowers.

Maple Bladder-Gall Mite (See Key, 20)
(Vasates quadripedes)

Hosts. — Red maple and silver maple.

Injury. — When very numerous, these galls may cover the leaves almost completely. The leaves will be disfigured and tend to turn color early; the following season the foliage may be pale and thin, giving the tree an unthrifty appearance. The injury is of importance on shade and ornamental trees, but is of no economic consequence in the forest.

Description. — The small, reddish, bladderlike galls, which are very noticeable early in the summer, are caused by a small blister-mite (fig. 46). The galls are green in the spring, later changing through dull purple to red. They are about one-eighth inch in diameter, and at the end of the summer they dry up and are black.

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FIGURE 46. — The bladderlike galls on red maple made by the maple bladder-gall mite.

Poplar-Gall Saperdas (See Key, 10)
(Saperda moesta)
(Saperda concolor)

Hosts. — Aspens and willow.

Injury. — Swelling or gall formation in small living twigs (usually less than three-fourths inch in diameter) on trees of all sizes and in the stems of suckers and seedlings. The first evidence of attack is the egg-laying incisions — those of *moesta* are horseshoe shaped and only one egg is laid in each, whereas those of *concolor* are longtitudinal (fig. 47) and one egg is laid at each end. Two to five incisions are made around a twig, and callous tissue over these incisions causes a globose gall. The larvae mine around the twig and then bore into the wood, where they make galleries about 1 inch long and parallel to the axis of the twig. Usually the infested twigs are not killed. Numerous galls on a single stem or branch cause a cessation of growth and susceptibility to wind breakage. Occasionally a gallery may become infected by *Hypoxylon* canker, resulting in death of the twig.

FIGURE 47. — The typical swelling in an aspen sucker caused by the poplar-gall saperda *(Saperda moesta)*. Note the horseshoe-shaped egg scar. (Photo courtesy of the University of Michigan.)

Description. — The adults are small beetles, about one-half inch long. The *moesta* adults are gray to black in color, while those of *concolor* are a uniform light gray. The mature larvae, about three-fourths of an inch long, are creamy-white and legless.

Gall-Making Maple Borer (See Key, 9)
(Xylotrechus aceris)

Hosts. — The maples, with red maple favored.

Injury. — Attacks originate at the base of a dead twig or in a wound. As a larva develops it tunnels in the sapwood and then into the heartwood, often destroying the central portion of the trunk. A swelling or gall is formed, which results in a deformity and breakage or means of entrance for secondary insects or fungi (fig. 48).

Description. — The adult is a moderately robust beetle about one-half inch long; the thorax is black with four yellow spots, and the wingcovers are light brown with indistinct whitish markings. The full-grown larva is slightly longer than the adult, cream colored, and legless.

FIGURE 48. — Attack by the gall-making maple borer. (Photo by D. C. Anderson, courtesy Canada Department of Forestry.)

FIGURE 49. — The knotty, gall-like swellings caused by the poplar-and-willow borer. (Photo courtesy of the New York State University College of Forestry at Syracuse University.)

Poplar-and-Willow Borer (See Key, 10)
(Sternochetus lapathi)

Hosts. — Aspens and willows.

Injury. — Young trees and nursery stock are most susceptible to attack, which usually occurs at the base of the trees. The young larvae feed in the outer sapwood layers and later bore toward the center of the stem. When the attack is heavy, the affected area will be honeycombed with galleries and breakage will occur. Broken places in the bark, through which the larvae push their frass, and knotty gall-like swellings are characteristic evidence of attack (fig. 49).

Description. — The adults are weevils, about three-eighths inch long, dark brown to nearly black in general color, and mottled with light brown and gray scales. The larvae are white, footless grubs and, when full grown are about one-half inch long.

Gall Wasps

Gouty Oak Gall (See Key, 7)
(Callirhytis punctata)
Horned Oak Gall (See Key, 7)
(Callirhytis cornigera)

Hosts. — Northern red oak and black oak.

Injury. — Death of twigs and even good-sized branches, due to development of rough, woody swellings. Often several galls are fused together into a continuous formation of abnormal woody tissue (fig. 50, left). This type of damage to ornamental trees is, at times, of considerable importance.

Description. — Swellings up to 1½ inches in diameter, containing numerous small larvae, which de-

FIGURE 50. — *Left*, gouty oak galls. (Photo courtesy Illinois Natural History Survey.) *Right*, a horned oak gall in cross-section to show holes at the base of the horns. (Photo courtesy U.S. Northeastern Forest Experiment Station.)

velop into gall wasps. The insects hibernate in the galls, emerge in the spring, and lay eggs in the developing buds. The galls of the horned oak galls have conelike projections which are hollow at the base (fig. 50, right).

Ribbed Oak Gall (See Key, 8)
(Andricus gemmarius)

Hosts. — The red oak.

Injury. — Death of twigs and branches when they are heavily infested. Occasionally young trees will be killed.

Description. — The galls are somewhat conical, strongly ribbed, and about one-quarter inch long. They form crowded masses in longitudinal cracks of the bark (fig. 51). In the summer the galls discharge a sweet secretion which attracts large numbers of bees and flies.

Oak Fig Gall (See Key, 8 and 18)
(Biorhiza forticornis)

Hosts. — White oaks.

Injury. — Numerous galls on the twigs and leaves. There is little damage to the leaves, but heavily infested twigs may be killed.

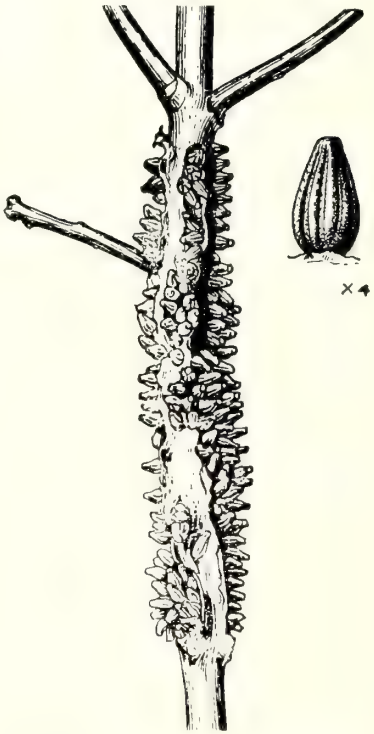

FIGURE 51. — Oak twig infested by the ribbed oak gall. (Drawing by E. P. Felt, courtesy of the U.S. Northeastern Forest Experiment Station.)

FIGURE 52. — The oak fig gall. (Photo courtesy of the U.S. Northeastern Forest Experiment Station.)

Description. — Early in the season these galls are reddish, bladder-like growths, each gall containing the larva of a small gall wasp. They measure up to one-half inch in diameter, and when they develop in a dense cluster around a twig they may be several inches long, in an irregular mass looking not unlike pressed figs (fig. 52).

Oak Flake Gall (See Key, 18)
(Neuroterus floccosus)

Hosts. — White oaks.

Injury. — Large numbers of galls, mostly singly along or near the veins on the undersurface of the terminal leaves. Heavily infested leaves curl and cause an unsightly appearance to shade and ornamental trees. Occasionally the galls may be found in flower clusters. The leaf curl becomes noticeable in July.

Description. — Small, hemispherical galls smooth at the leaf surface and thickly covered with white wooly hairs below (fig. 53.) The adults are small gall wasps.

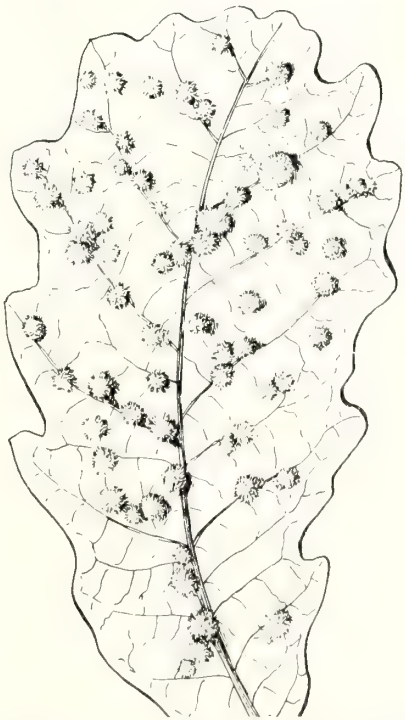

FIGURE 53. — The oak flake gall. (Courtesy American Museum Natural History.)

FIGURE 54. — The large oak-apple gall. (Photo courtesy Illinois Natural History Survey.)

Large Oak-Apple Gall (See Key, 17)
(Amphibolips confluentus)

Hosts. — Principally red, black, and scarlet oaks.

Injury. — The injury is of little economic consequence; aesthetically, it may be important in that a large number of galls, especially when they are mature, gives the tree an unsightly appearance.

Description. — The mature insects are small, gall wasps which appear early in the spring; the eggs are laid in the tissues of the leaves or the petioles. The globose galls are ½ to 2 inches in diameter and are conspicuous. As they develop, they change from green to brown (fig. 54). One larval cell is in the center of the gall, which is filled with a spongy mass of fibers.

SUCKING INSECTS

Aphids and scales are common pests in open-growing hardwood stands and ornamental trees. Some species, when abundant, can kill branches or weaken a tree so that it is less resistant to drought conditions or to successful attack by wood borers or fungi. The lace bugs and leafhoppers and the like are other forms of sucking insects which cause foliar damage to numerous hardwood species. In some cases they may act as vectors for disease organisms.

Diagnosis of tree damage by sucking insects generally depends upon identification of the pest itself. Though the individual insects are small, they are usually present in great numbers, covering leaves, twigs, or whole stems. Frequently a waxy or wool-like substance covers the pests and is useful in identification. In scales, the characteristic color and shape of the "shells," which usually persist even on dead individuals, will aid in identification. Aphids and other pests frequently cause an overgrowth of host tissue (gall). These are treated in a separate section, headed "Gall Makers."

The reaction of the tree to damage by sucking insects is usually characterized by wilted leaves, dying branches, reduced growth, etc. If these symptoms are observed but the pests cannot be found on the trees, they may still not be ruled out as the causal agents. Many species of aphids spend only part of their lives on the primary (tree) host and the rest on particular alternate hosts — usually specific shrubs and herbs.

Aphids

Woolly Elm Aphid (See Key, 24)
(Eriosoma americanum)
Woolly Apple Aphid (See Key, 24)
(Eriosoma lanigerum)
Woolly Elm Bark Aphid
(See Key, 24)
(Eriosoma rileyi)

Hosts. — Elms.

Injury. — Leaf curling by the first two species from early spring to midsummer. When growth begins in the spring the aphids that have hatched from the overwintered eggs begin to feed on the developing elm foliage, causing the affected leaves to curl (fig. 55). The resulting generations of aphids are produced in these leaves. Although most of the leaf curl occurs in the spring, it may also be noticeable during the summer due to activity of the later generations. The woolly masses of the bark aphid are found on the branches, and heavy attacks kill small branches.

Description. —The two leaf aphids (woolly elm and woolly apple) look much alike; they are purple and are clothed with a white woolly waxy covering. There are several generations annually, and in many cases species can be determined by the presence of an alternate host on which at least one generation develops. Serviceberry is the alternate host for *americanum*, while apple is the alternate host for *lanigerum*. American elm is the only known host for *americanum*; but most of the elms are attacked by *lanigerum*. The closely related woolly elm bark aphid is brown bodied and covered with a white woolly wax. The entire development is spent on elm.

FIGURE 55. — Leaf curl caused by the woolly elm aphid. (Photo courtesy Pennsylvania State University.)

Scales

European Elm Scale (See Key, 31)
(Gossyparia spuria)

Hosts. — Elms, chiefly on shade and ornamental trees.

Injury. — Heavy nymph populations result in foliage yellowing, and honeydew excreted by the female scales causes formation of a sooty mold. Premature leaf drop and death of twigs follow. Young trees may be killed, and older trees may be weakened sufficiently to permit further decadence and death by drought and bark beetle and fungus attacks.

Description. — The reddish-brown oval-shaped adult female has a conspicuous, waxy fringe along the body margin (fig. 56). The young nymphs (crawlers) are bright yellow and very small. They feed and develop along the main leaf veins; in the fall they migrate to the branches and hibernate in bark crevices.

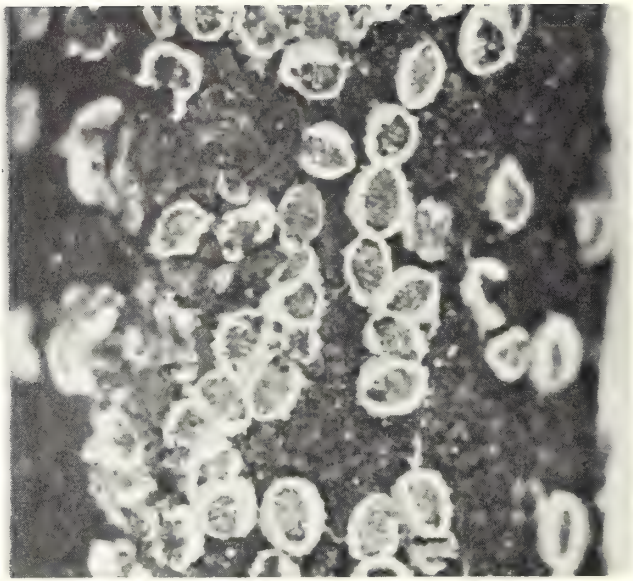

FIGURE 56. — Female European elm scales; the waxy fringe is conspicuous. (Photo courtesy Illinois Natural History Survey.)

Elm Scurfy Scale (See Key, 31)
(Chionaspis americana)

Hosts. — Elm and hackberry.

Injury. — Death of twigs, branches, and even small trees when there is an abundance of these scales. Large trees may be sufficiently weakened by heavy attacks to permit successful attack by wood-boring insects.

Description. — The mature females are shaped like oystershells and are about one-eighth inch long. They are dirty-white in general color, and frequently the front part is grayish (fig. 57). When a scale is removed a whitish scar remains on the bark. The male scales are very small, less than one twenty-fifth inch long; they are found on the bark and on the undersurface of the leaves. The closely related scurfy scale, *Chionaspis furfura,* is also found on elm, ash, aspen, maple, and other hardwood hosts. The females are pear-shaped, are slightly smaller than those of *C. americana,* and somewhat darker.

Maple Leaf Scale (See Key, 30)
(Pulvinaria acericola)
Cottony Maple Scale (See Key, 30)
(Pulvinaria innumerabilis)

Hosts. — Silver maple is the preferred host, but other maples and even other hardwood species may be attacked.

Injury. — The nymphs (crawlers) of these two species of sucking insects feed on the lower surface of the leaves and on the twigs. Large white cottony masses, popcorn-like in appearance, may be found in the spring on the twigs and branches (fig. 58). The foliage is covered with honeydew and a sooty fungus. These attacks cause yellowing and early foliage drop, and death of the twigs. Heavy populations may kill larger branches or even an entire tree.

Description. — The adult females of the cottony maple scale are elongate-oval, brown soft scales nearly three-tenths inch in length and slightly less in width, with a conspicuous elongate white egg sac.

FIGURE 57. — A heavy infestation of the scurfy scale, which is similar to the elm scurfy scale. (Photo courtesy of the Illinois Natural History Survey.)

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FIGURE 58. — Hibernating cottony maple scales on silver maple twigs.

Those of the maple leaf scale are dark purple with a brown stripe down the middle. They are about one-quarter inch long and also bear the white egg sac. The crawlers, which are found principally along the veins on the lower leaf surface, are small, oval, and brown. The cottony maple scale hibernates as an adult female on the twigs, while the maple leaf scale hibernates as a partially developed nymph on the twigs. The egg masses are produced in the spring.

Oystershell Scale (See Key, 32)
(Lepidosaphes ulmi)

Hosts. — Ash, birch, aspen, maple, elm, basswood, and willow. More than 125 plant species are subject to attack.

Injury. — Twigs and small branches may be encrusted with these scales; the first evidence of attack, however, is early yellowing of foliage. Heavy feeding will retard growth and often kill twigs and even large branches. Ash reproduction may be seriously affected. The spread from tree to tree is slow because it must be done by the crawlers, which are first-instar nymphs.

Description. — The mature female scales look like miniature oystershells, hence the name (fig. 59). They are about one-eighth inch long, broad and rounded at the rear, and narrow in front. The color varies from dark brown in summer and fall to gray in winter. The males are smaller but are very rare. The pale yellow female crawlers hatch from the overwintered eggs in late May and early June. They feed on the plant tissues and produce a mass of waxy threads. By early August these females have matured and have laid their eggs under the hard brown scale covers.

FIGURE 59. — Oystershell scale. (Photo courtesy of Pennsylvania State University.)

San Jose Scale (See Key, 36)
(Aspidiotus perniciosus)
Putnam Scale (See Key, 36)
(Aspidiotus ancylus)

Hosts. — Ash, basswood, birch, and elm.

Injury. — Removal of sap by these sucking insects retards growth and kills branches. Heavily infested trees, with dead and dying branches, look weak and sickly. There may be two generations, but cold weather and natural enemies kill many scales and generally prevent heavy damage.

Description. — The mature female scales are round, with a dark central nipple (fig. 60). They are gray and about one-sixteenth inch in diameter. The tiny, young crawlers are yellowish. They soon begin forming

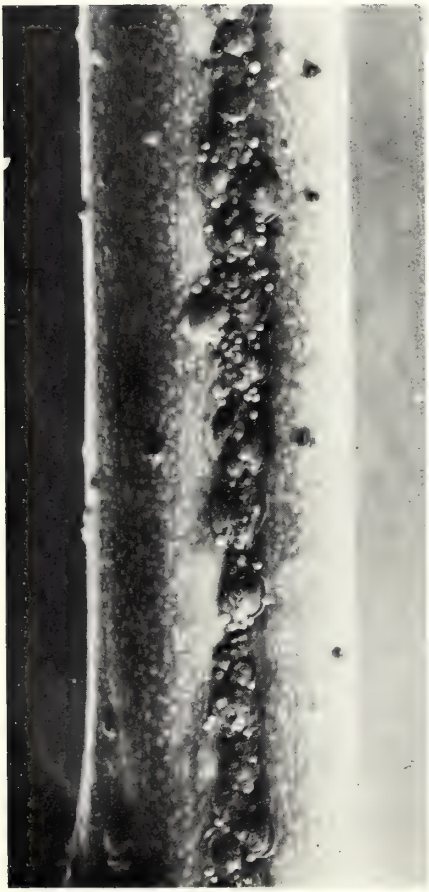

FIGURE 60. — The San Jose scale. The large forms are mature females; the small ones are the young scales which have developed from the new generation. (Photo courtesy of The Connecticut Agricultural Experiment Station.)

a whitish scale covering, which gradually darkens and becomes dark gray or black.

The closely related Putnam scale is about the same size and shape as the San Jose scale, but the females are a little darker and the nipple is off center and a brick red. Favored hosts are basswood and soft maple.

Terrapin Scale (See Key, 35)
(Lecanium nigrofasciatum)

European Fruit Lecanium (See Key, 35)
(Lecanium corni)

Hosts. — Maple, elm, hickory, walnut, butternut, and sycamore.

Injury. — Heavy scale populations secrete tremendous amounts of honeydew during the early summer, and a sooty mold develops. The trees lose vigor and appear unhealthy. Small branches may be killed.

Description. — Following hibernation, the female terrapin scales mature in the spring. They are about one-eighth inch long, and somewhat oval and very convex in shape. Their general color is reddish brown (fig. 61), and numerous black bands radiate from the center to the edges. They are often covered with a whitish powdery substance. The tiny newly hatched young are yellowish and found along the leaf veins. As they develop, they migrate to the bark of the twigs and small branches. There is one generation annually in the northern states. The closely related European fruit lecanium, or brown elm scale, also infests a wide range of forest tree hosts. The mature females are smaller and darker than those of the terrapin scale, and the black bands are absent. The life history and injury are similar.

Golden Oak Scale (See Key, 33)
(Asterolecanium variolosum)

Hosts. — Oaks.

Injury. — Gall-like pits in the bark wherever these scales have settled to feed. Reproduction and sprout growth are most seriously affected, and heavy infestations will cause death. Branches of large trees

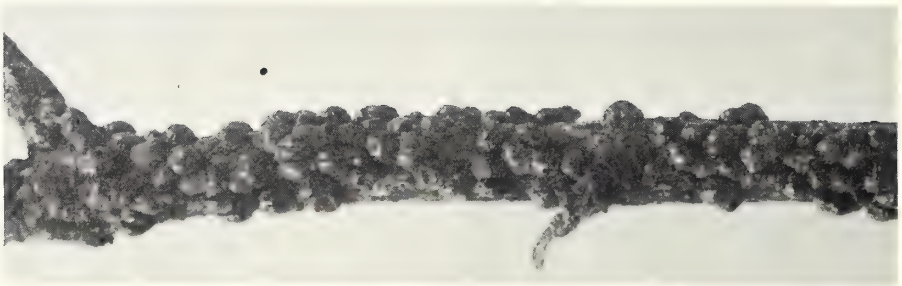

FIGURE 61. — A small branch heavily infested by the terrapin scale. (Photo courtesy of The Connecticut Agricultural Experiment Station.)

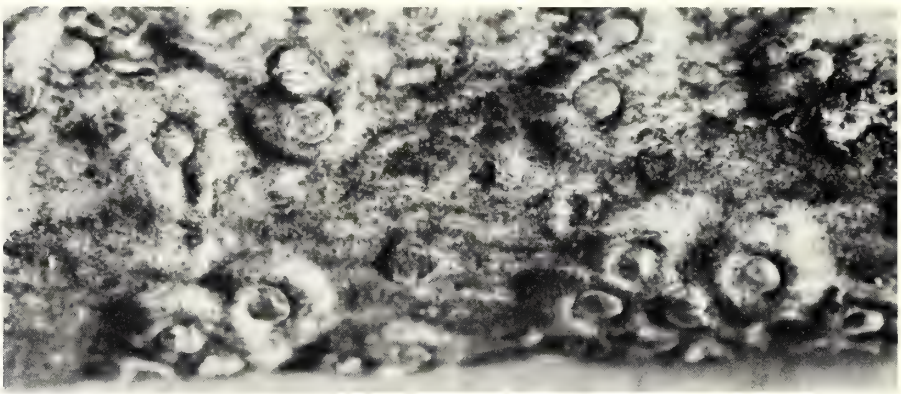

FIGURE 62. — The golden oak scale. Note the depressions on the bark. (Photo courtesy of the Bartlett Tree Expert Company.)

may be killed and, when heavy attacks are followed by drought, mature trees may be severely weakened or die.

Description. — The female scales are circular, slightly convex, about one-sixteenth inch in diameter (fig. 62), and greenish-gold in general color. These scales can be readily recognized by the pitlike depressions in the bark.

Lace Bugs

Elm Lace Bug (See Key, 24)
(Corythucha ulmi)
Sycamore Lace Bug (See Key, 24)
(Corythucha ciliata)

Hosts. — American elm in natural stands and in shelterbelts as well as shade trees. Siberian elm in shelterbelts.

Injury. — Feeding by developing nymphs. The undersurface of leaves is speckled with eggs, excrement, and cast nymphal skins (fig. 63), and the surface is discolored. In heavy infestations, trees lose most of their leaves and may be seriously weakened, particularly during a drought period. The closely related sycamore lace bug sometimes causes severe damage to street and shade trees. A species, *C. arcuata,* is a pest

of bur oak in shelterbelts and one, *C. pallipes,* is often abundant on birch in Wisconsin.

Description. — The adults have characteristic lacy wingcovers with prothoracic expansion. The head is covered with a lacelike arching hood. The length, depending on the species, varies from one-eighth to one-quarter inch. The nymphs are dark brown to black, have spiny projections, and increase in length as they develop.

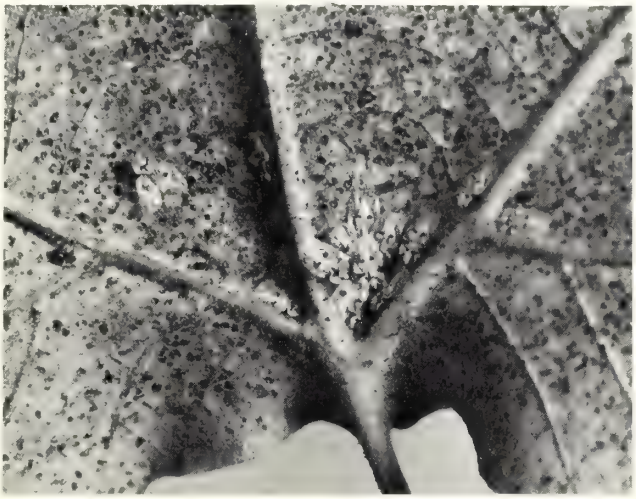

FIGURE 63. — Typical speckling on leaf undersurface caused by lace bug feeding. A cluster of bugs can be seen at the vein junction. (Photo courtesy of The Connecticut Agricultural Experiment Station.)

BUD, TWIG, BRANCH, AND STEM BORERS

The borers are differentiated from the previous groups of insects on the basis of their feeding habits —they feed on the wood rather than on the leaves or plant juices. Also, their feeding does not induce a typical gall formation in the affected tree part.

The larvae (and the adults in a few cases) of a variety of beetles, moths, ants, wasps, and flies attack all parts of hardwood trees from the buds and twigs to the roots. Many of the species may be attracted to weakened trees; their activities may hasten death of the tree and cause lumber degrade. On the other hand, certain species, especially the true wood borers, can successfully attack vigorous trees; extensive larval galleries in the sapwood and heartwood may result in girdling, stem breakage, and lumber degrade. Pith-ray flecks do not seriously affect tree health, but do result in a reduced value of the finished wood because of a spotty discoloration.

The activities of insects belonging to this group are generally not readily apparent. For example, even heavy infestations of certain wood borers may escape notice by those who have day-to-day contact with the affected trees. The most common damage symptom is the death or deformation of the affected tree part. Since the death of, say, a branch is a nonspecific symptom, the cause can be determined only by careful inspection for characteristic egg niches, galleries, exit holes, and the insect specimens themselves.

Some of the primary wood borers can be diagnosed simply on the basis of the tree species affected and condition of the tree. For example, insects tunneling in the stems of apparently healthy aspen are usually larvae of the poplar borer, *Saperda calcarata.*

Buds and Twigs

Maple Bud Borers (See Key, 26)
(Proteoteras spp.)
Boxelder Twig Borer (See Key, 37)
(Proteoteras willingana)

Hosts. — Boxelder in nurseries, windbreaks, and shelterbelts and as ornamentals in the northern Great Plains; sugar maple in the northern Lake States.

Injury. —The boxelder twig borer destroys the dormant buds in the fall as well as in the spring, and tunnels in the current season's shoots (fig. 64). These shoots are killed and terminal growth prevented; forking and occasionally twig breakage result. In heavy infestations many of the twigs on a single tree will be infested and the trees will become bushy. The maple bud borers also destroy the buds in the spring; the resulting forked growth is a serious deformity in reproduction and small sugar maple saplings.

Description. — The adults are small moths with a wingspread of five-eighths inch; they are white to pale brown. The full-grown caterpillars are about one-half inch long, and are whitish yellow with a dark-brown head capsule.

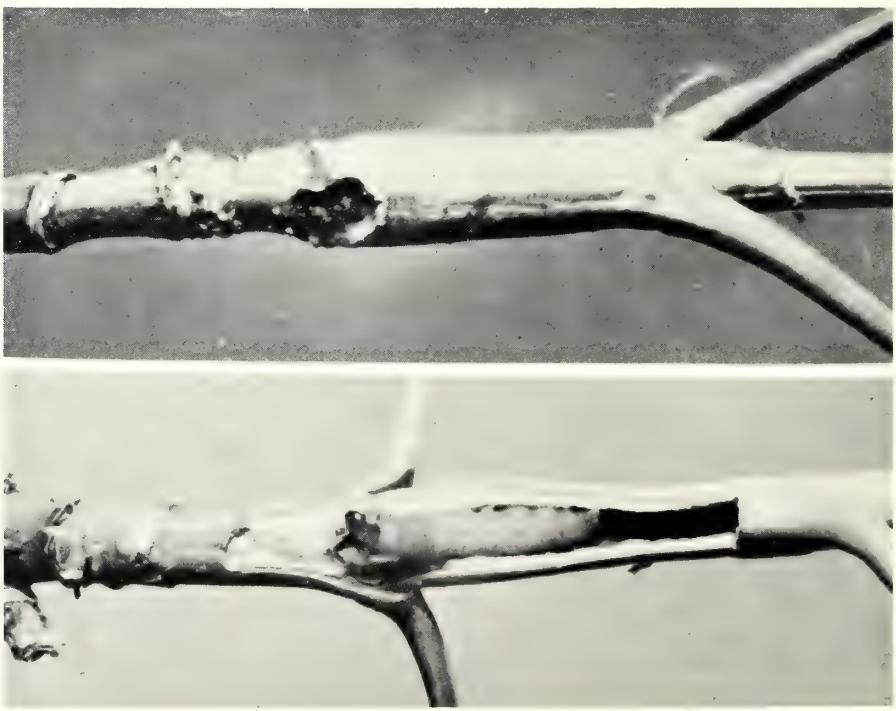

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FIGURE 64. — *Top,* boxelder infested by the boxelder twig borer. *Bottom,* portion of a stem removed to show a borer.

Locust Twig Borer (See Key, 37)
(Ecdytolopha insiticiana)

Hosts. — Black locust.

Injury. — Irregular, elongate swellings in the new growth, 1 to 3 inches long (fig. 65). Old swellings often crack open, and when they are numerous twig growth may be retarded.

Description. — A twig borer, the full-grown caterpillar is one-half to three-quarters inch long. The head is dark brown, and the body reddish to straw yellow, and darker along the dorsal line. The moth is grayish-brown and has a wing expanse of about 1 inch.

FIGURE 65. — The swellings caused by the locust twig borer. (Photo courtesy of Duke University School of Forestry.)

Poplar Twig Borer (See Key, 37)
(Oberea schaumii)

Hosts. — Aspen.

Injury. — Longitudinal tunnels in the center of living twigs, usually less than three-fourths inch in diameter, of saplings, poles, and larger trees, and in stems and branches of suckers and seedlings. "Push-out"

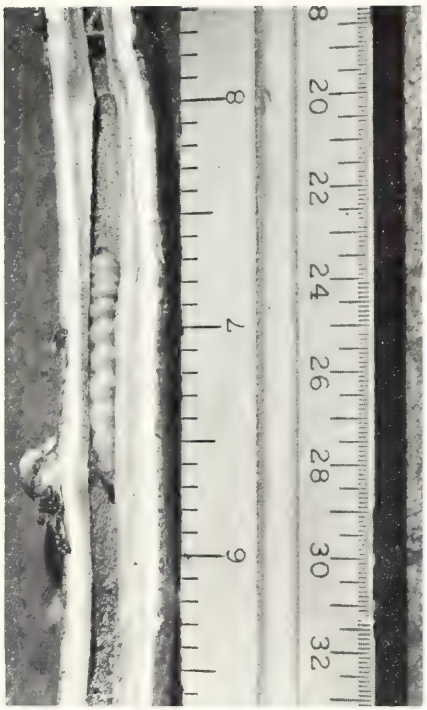

FIGURE 66. — A mature poplar twig borer in the center of an aspen twig. (Photo courtesy of the University of Michigan.)

holes are made, through which borings and frass are expelled, thereby keeping the tunnels clean (fig. 66). Black, necrotic areas develop around these holes. Generally the twigs are not sufficiently weakened to allow wind breakage.

Description. — The adults are slender beetles, about five-eighths inch long, with yellowish or black wing covers and four round black spots on the thorax. The full-grown larvae are about three-fourths inch long, yellow, and legless.

Twig Pruner (See Key, 37)
(Elaphidion villosum)

Hosts. — Many hardwoods, chiefly oak, maple, and hickory.

Injury. — Pruning of living branches. Attack begins with egg-

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FIGURE 67. — Oak twigs pruned by the twig pruner.

laying in the axil of a leaf near the tip of a twig; twig mining by the early stage larva follows. As the larva develops it tunnels down the stem, and late in the summer it makes concentric cuts outward from the center except for the bark. It retreats into the severed portion to hibernate, appearing as a beetle in the spring. The severed branches, sometimes 2 inches in diameter, break off in the wind (fig. 67). This is not an important forest insect, but heavily infested shade trees are unsightly.

Description. — The adult is a brownish beetle, about three-quarters inch long, with a pair of short spines at the tip of each wingcover. The full-grown shiny-white larva is slender and slightly longer than the adult. The closely related spined bark borer (*Elaphidion mucronatum*) is similar in general appearance, but it is a little larger and has stronger spines. The eggs are laid on dead twigs, and the larva feeds beneath the bark during the first season, exuding granular frass. The second season it tunnels in the sapwood. Prior to pupation it severs the branch in the same way as the twig pruner.

Birch and Beech Girdler (See Key, 37)

(Xylotrechus quadrimaculatus)

Hosts. — Birch, beech, and maple.

Injury. — Somewhat similar to the damage by the twig pruners in that branches up to 2 inches in diameter are severed or girdled (fig. 68). The cutting, however, is from the outside to the center, and a few strands of wood between the concentric cuts remain. Hibernation occurs in the severed portion, and development is completed in 1 year.

Description. — The adult is a moderately robust beetle, about five-eighths inch long; the thorax is black, marked with four yellow spots, and the wingcovers are pale brown with faint white markings. The larva is rather robust, cream colored, and somewhat longer than the adult when full grown.

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FIGURE 68. — Gallery made by the birch and beech girdler.

Larger Branches and Stems

Eastern Ash Bark Beetle
(See Key, 39)
(Leperisinus aculeatus)
White-Banded Ash Bark Beetle
(See Key, 39)
(Leperisinus fasciatus)

Host. — Ash.

Injury. — Girdling caused by tunneling in the inner bark and the surface of the sapwood (fig. 69). Attacks are confined to trees that have been weakened by fire, disease, or mechanical injury — thereby hastening death of the affected part or the entire tree.

Description. — The egg tunnels are forked and across the grain of the wood. The adults of the eastern ash bark beetle are rather stout, dark brown with light tan and gray scales, and a little less than one-eighth inch long. Those of the white-banded ash bark beetle are slightly smaller and are black with white markings. The larvae of both species are white, footless, and, when full grown, slightly longer than the adults.

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FIGURE 69. A branch with the bark removed to show ash bark beetle tunnels. The horizontal ones are egg tunnels; the vertical ones, larval tunnels.

Cambium Miner (See Key, 40)
(Phytobia pruinosa)

Hosts. —Birch, cherry, and maple.

Injury. — Larvae cause defect in lumber, known in the industry as pith-ray fleck. Attack usually begins in suppressed twigs in the spring and progresses down the stem between the surface of the cambium and the inner bark to the base of the tree and even into the roots. The full-grown larvae bore through the bark at the ground level early in the summer and pupate in the soil, passing the winter there. Trees are not killed, and the infestation cannot be detected unless the bark is removed (fig. 70, left). Each year's attack, however, will be evident in a cross-section of a log (fig. 70, right). A disintegration of the woody tissue may result, due to the pith flecks; and heavily infested logs may not be suitable for high-grade veneers or cabinet stock.

Description. — The adults are small flies with membranous wings. The small maggotlike larvae are white and very slender.

Bronze Birch Borer (See Key, 40)
(Agrilus anxius)
Bronze Poplar Borer (See Key, 40)
(Agrilus liragus)
Two-Lined Chestnut Borer (See Key, 40)
(Agrilus bilineatus)

Hosts. — Birch for the bronze birch borer; aspen for the bronze

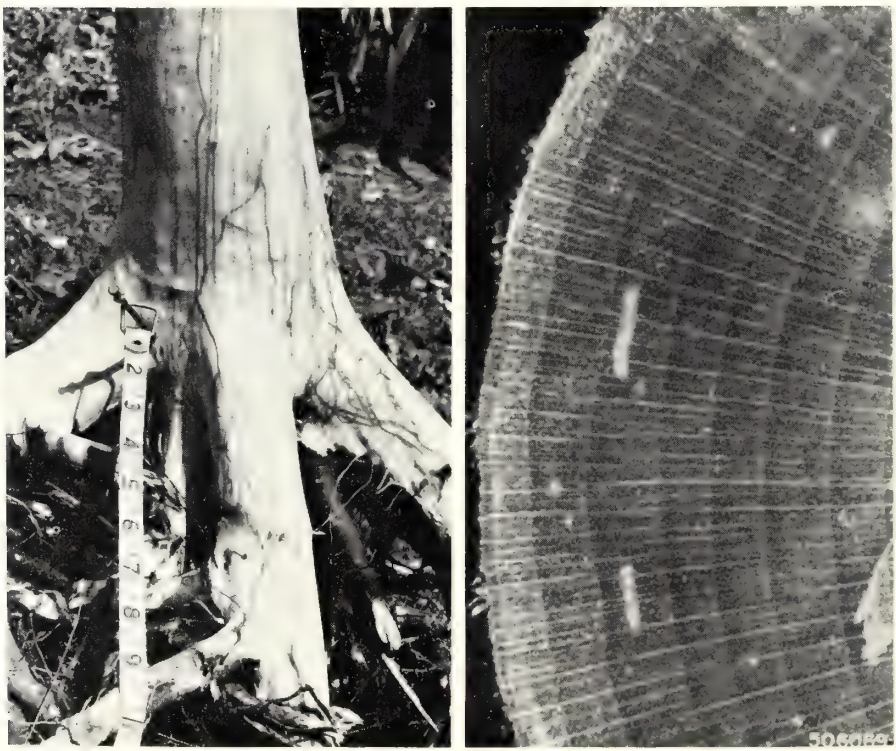

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FIGURE 70. — *Left*, the appearance of attack in the cambium by cambium miners; *right*, pith-ray flecks in a cross-section of a log.

poplar borer; and oak for the two-lined chestnut borer.

Injury. — Trees of low vigor or weakened in some manner are especially subject to successful attack. After heavy defoliation or after logging operations, attacks by these insects may hasten death of overmature or defective trees and of young trees suddenly released by the removal of dominant trees. The type of larval gallery for each species is very characteristic. The typical meandering galleries made by the bronze birch borer are shown in figure 71, left; those of the bronze poplar borer are typically compact as shown in figure 71, right. Galleries in oak by the closely related two-lined chestnut borer are of the meandering type. In all three species, attacks usually begin in the crowns and progress downward into the bole, thereby causing death. Vigorous trees, even though weakened by defoliation, disease, drought, etc., may withstand attack, healing over the galleries and killing the larvae. Successful attacks do not weaken the trees structurally.

Description. — The adults of the species on birch and aspen are about half an inch long and olive-bronze in general color. Species determination in the field is difficult and should be restricted to host preference. The adults of the two-lined borer are blackish blue, with golden yellow longitudinal stripes on the prothorax and the wing covers. The larvae of all three species are pearly white, slender, flattened, and about 1 inch long when full grown.

Ash Borer (See Key, 44)
(Podosesia syringae fraxini)

Hosts. — Green, white, red, and European ashes. An important pest in shelterbelts.

Injury. — Tunneling in branches and trunks, young trees being more seriously injured than large trees (fig. 72). The smaller branches break at the point of injury. Attack is usually made evident by the appearance of rough, irregular scar-like swellings on the trunks.

FIGURE 71. — *Left*, the meandering galleries made by the bronze birch borer. *Right*, the compact galleries made by the bronze poplar borer. (Photo courtesy R. F. Anderson, Duke University.)

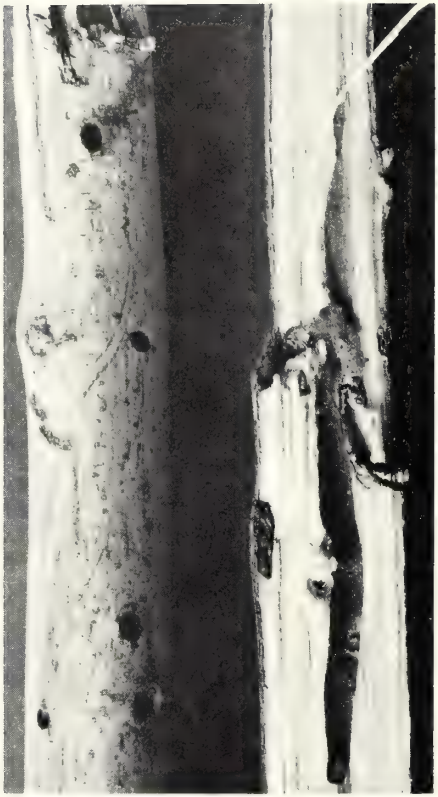

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FIGURE 72. — Tunneling in ash by the ash borer. Note the cast pupal shells.

Description. — A clear-wing moth with a wing expanse of about 1 inch. The forewings are an opaque dark brown with a red cross bar; the hind wings are transparent. The full-grown caterpillar is whitish, with a mahogany colored head, and is about three-fourths inch long.

Maple Callus Borer (See Key, 44)
(Sylvora acerni)

Hosts. — Maples.

Injury. — Attacks usually develop near wounds on the boles of trees. The outer bark will be rough and callused and the sapwood will have scar tissue (fig. 73). Brown, powdery frass will be found in the feeding cavity and on the bark. Cast pupal skins may be noticeable, sticking out of the bark in the callused area. Continued infestation weakens a tree, complete girdling sometimes occurring.

Description. — The adult is a tawny clear-wing moth, with a reddish tuft at the tail. The full-grown caterpillar is about one-half inch long, with a whitish body and a brown head.

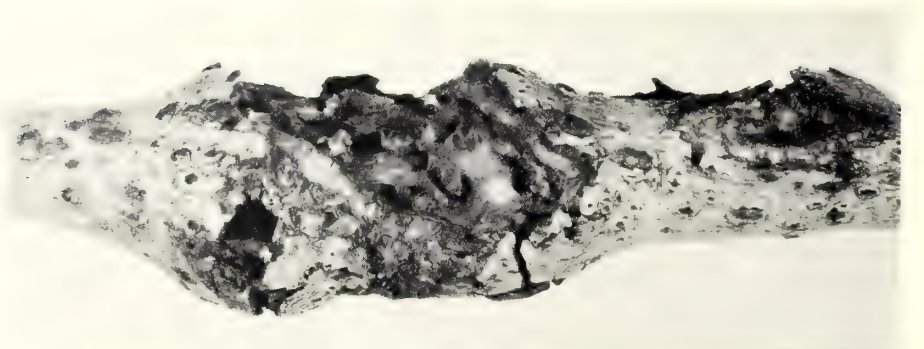

FIGURE 73. — The maple callus borer causes the roughened, callused area shown here. (Photo courtesy of New York State University, College of Forestry at Syracuse University.)

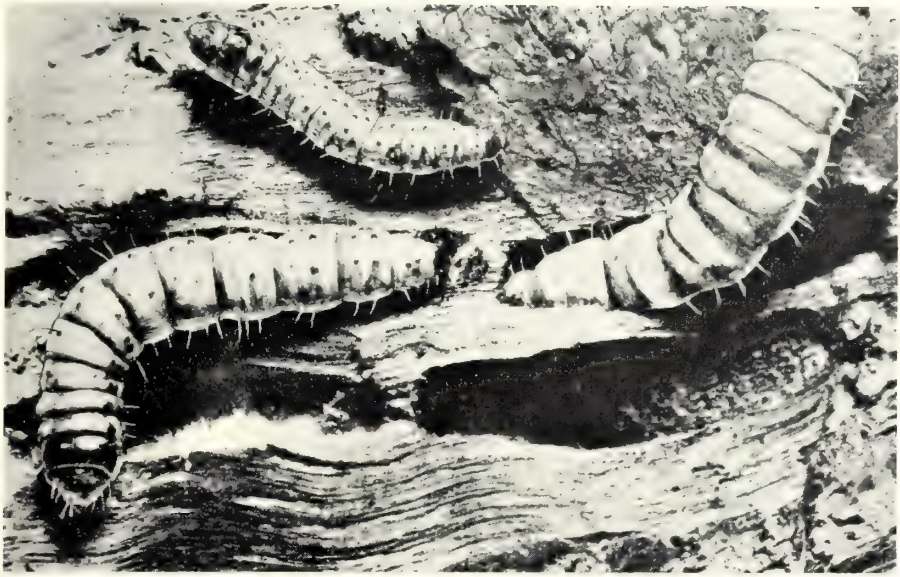

FIGURE 74. — Galleries and larvae of the carpenterworm. (Photo courtesy of the U.S. Northeastern Forest Experiment Station.)

Carpenterworm (See Key, 43)
(Prionoxystus robiniae)

Hosts. — Oaks, green ash, maple, birch, and aspens.

Injury. — Tunnels in the bark, sapwood, and heartwood of living trees, with associated stain and wood decay, cause lumber degrade (fig. 74). Oval or irregular scars in the bark are evidence of infestation. Damage in lumber appears as oval, oblong, or irregular holes, ½ to 1½ inches in diameter, surrounded by stained wood often extending as much as 2 feet up and down from the gallery.

Description. — The adult is a grayish, stout-bodied moth, uniformly mottled with gray and brown scales. The full-grown caterpillar is 2 to 3 inches long, and greenish white with a shiny brown head and nearly black mandibles (biting mouthparts). The life cycle in the northern states requires 3 to 4 years.

Oak Timberworm (See Key, 46)
(Arrhenodes minutus)

Hosts. — Oak, beech, and aspen.

Injury. — Cylindrical holes in or near wounds caused by broken branches or by fires, or in recently felled or dying trees. The eggs are deposited singly in these holes in May and June and the larvae bore into the sound wood, extending their galleries in all directions. This may cause a high degree of degrade and make logs unfit for special uses such as tight cooperage or flooring (fig. 75).

Description. — The adults are shiny reddish-brown snout beetles, with the wing covers marked by elongate yellowish spots. The males are about one-half inch long and have a broad flat snout; the females are larger than the males and have a long slender snout used in making the cylindrical holes where the eggs are deposited. The larvae are elongate and cylindrical, and have min-

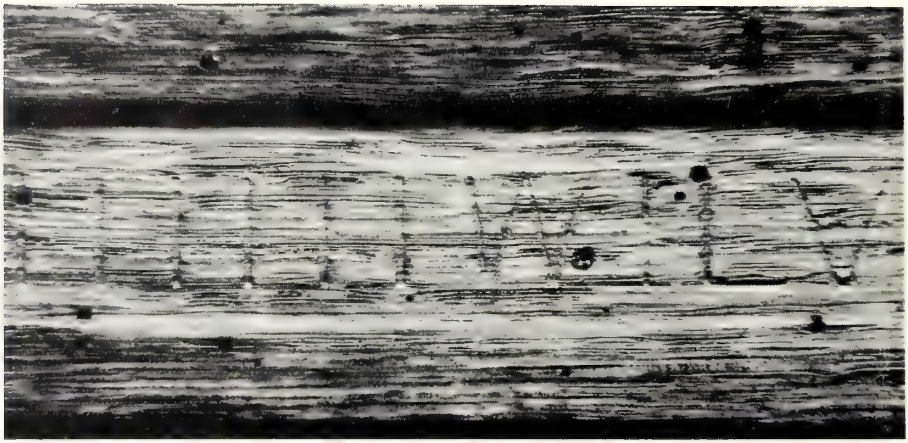

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FIGURE 75. — Oak flooring with pinhole galleries made by the oak timberworm.

ute two-jointed legs. When full grown, they are about three-fourths inch long.

Black Carpenter Ant (See Key, 42)
(Camponotus pennsylvanicus)

Hosts. — Oaks.

Injury. — Galleries in the heartwood of forest trees are generally at the base of decayed or weakened trees or in stumps (fig. 76). Logs, telephone poles, or even the framework of buildings may be damaged. In hardwood trees the galleries are usually separated. Carpenter ants do not eat the wood; rather they are predatory on certain caterpillars and also obtain honeydew from aphids. The wood is excavated in the construction of the ant nests, and little piles of "sawdust" are evidence of attack.

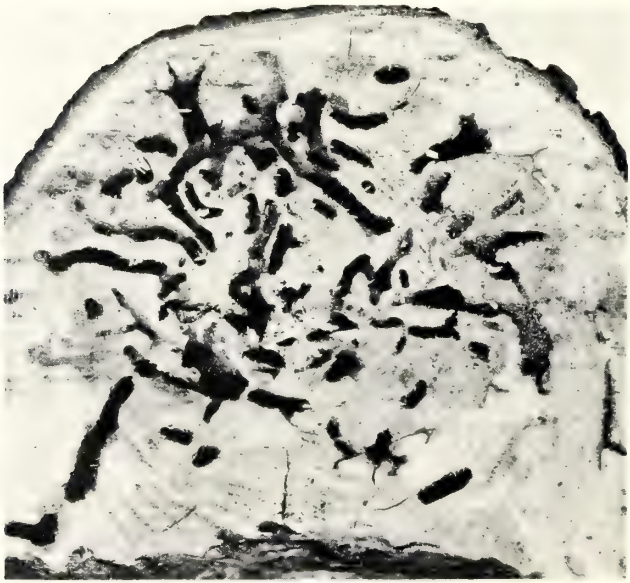

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FIGURE 76. — Cross-section of an oak log showing galleries made by carpenter ants.

FIGURE 77. — *Left*, open, wet wounds caused by sugar-maple borers. (Photo by D. C. Anderson, courtesy Canada Department of Forestry.) *Right*, callous tissue formed over a borer gallery. (Photo courtesy New York State University, College of Forestry at Syracuse University.)

Description. — The black carpenter ant varies in color from dark brown to deep black. The worker ants vary in size, and sometimes exceed a half inch in length. All stages of these insects — eggs, larvae, workers, and a queen — may be found in an active nest.

Sugar-Maple Borer (See Key, 45)
(Glycobius speciosus)

Host. — Sugar maple.

Injury. — This borer is a serious primary enemy; vigorous trees are attacked, especially those in the open or in understocked stands where the trees are in full light. The first symptoms of infestation are moist spots on the bark and frass pushed out through holes at the points of attack. Sometimes the bark cracks at these points, leaving open, wet wounds (fig. 77, left). Two years are necessary to complete development. Not only are parts of the tree killed, but also callous tissue forms over the larval galleries and causes ridges or gall-like swellings on the wood surface (fig. 77, right). Deep galleries, made across the grain of the wood during the second season of larval activity, lead to defect and degrade.

Description. — The adults are robust black beetles, about 1 inch long, with bright yellow markings on the thorax and wingcovers. One of the markings on the wings is a distinct W. The larvae are grayish white and about 2 inches long when full grown. They have three pairs of thoracic legs.

Red-Oak Borer (See Key, 45)
(Romaleum rufulum)

Hosts. — Oaks.

Injury. — Granular frass pushed out from points of attack and wet spots caused by sap leakage from these wounds are conspicuous evidence of early attack. As the larvae develop they bore into the heartwood and, during the second year, make large tunnels. Ants and fungi enter these tunnels and extend the injury, the end result being defects

and serious lumber degrade. Two years are required for development.

Description. — The rather robust beetles, about 1 inch long, are brownish and spotted with yellowish, fine soft hair. Thoracic spines are absent. The shiny white larvae have true legs on the thorax and, when full grown, are slightly longer than the adults.

White-Oak Borer (See Key, 45)
(Goes tigrinus)

Hosts. — White oaks.

Injury. — Galleries in living white oaks similar to those made by the red-oak borer. This species may cause a considerable amount of degrade in tight cooperage stock due to the extensive tunneling in the sound wood. Four or five years are required for full development.

Description. — The beetles are about 1 inch long, dark brown, and densely clothed with white, fine soft hairs. Thoracic spines are present. The larvae are creamy yellow, legless, and, when full grown, slightly longer than the adult.

Poplar Borer (See Key, 45)
(Saperda calcarata)

Hosts. — Aspen.

Injury. — An important primary pest of living trees, the attack is characterized by swollen scars and holes in the trunk and larger branches. "Push-out" holes are made by the feeding larvae through which frass is expelled and sap exudes. The wet areas around these holes are blackened, appearing as if varnished (fig. 78, left). The poplar borers require 3 years to develop, mining deep in the heartwood during this period (fig. 78, right). Heavily infested trees break at points weakened by this tunneling. A serious secondary injury is the development of wood-rotting fungi with resulting additional timber degrade.

Description. — The adult beetles are about 1 inch long, grayish black, and densely clothed with gray and yellow fine soft hairs; they have yellowish stripes on the thorax and orange-yellow markings on the wing

FIGURE 78. — *Left*, external appearance of an aspen attacked by the poplar borer. The black spots are egg-niche scars, and the black streaks are the blackened "varnished" areas caused by sap leakage. *Right*, a section of a stem showing heavy larval attack. (Photos courtesy of the University of Michigan.)

covers. The larvae are creamy white, legless, and about 1¼ inches long when full grown.

Cottonwood Borer (See Key, 45)
(Plectrodera scalator)

Hosts. — Aspens and willows.

Injury. — This insect is injurious to cottonwood and willows in shelterbelts. Small-diameter trees are preferred, and the heaviest attack occurs at the base, abnormal swellings being common. The larvae tunnel under the bark, pushing out large amounts of frass. The trees are girdled and the sap movement is cut off. Breakage often occurs just below the ground line. Some damage is done in midsummer when the beetles feed on the tender bark of small branches. Development to the adult stage takes 2 years.

Description. — The adults are black robust beetles nearly 1½ inches long, and are thickly mottled with white or creamy patches or stripes. There is a small spine on each side of the thorax. The larvae are yellowish white, legless, and about 2 inches long when full grown.

Locust Borer (See Key, 45)
(Megacyllene robiniae)

Host. — Black locust.

Injury. — Slow-growing, overtopped trees on poor sites are most seriously damaged, particularly during drought periods. Thrifty trees are attacked but they can, in most instances, withstand heavy injury. Wet spots on the bark, the result of feeding activity by the early stage borers soon after growth starts in the spring, are evidence of infestation. The borers tunnel into the sapwood, expelling white dust which will be noticeable in bark crevices and at the base of the tree. As they develop they make galleries deep in the wood and lengthwise of the stem (fig. 79, left). There is one generation annually. Repeated attacks over a period of years result in numerous dead and broken limbs and knotty swellings on the trunk. Heavily infested trees are subject to wind breakage (fig. 79, right).

Description. — The adults, about three-fourths inch long, are jet black beetles with numerous bright yellow bands. Four of these extend across

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FIGURE 79. — *Left*, locust borer galleries deep in the wood. *Right*, windbreakage resulting from repeated attacks. Note the knotty swellings.

the thorax, while those on the wingcovers are roughly W-shaped. They may be found in late summer and early fall feeding on the pollen in goldenrod blossoms. The larvae are white, legless, and about 1 inch long when full grown.

Elm Borer (See Key, 45)
(Saperda tridentata)

Hosts. — Elms.

Injury. — Wide, shallow galleries in the inner bark and outer layers of the sapwood filled with fibrous frass. Attack begins in limbs and injured areas on the trunk, and mortality occurs when these galleries make a complete girdle. As the larvae develop, they bore into healthy wood. Usually larger branches die before the tree does. There is one generation annually. Damage in forest areas is not important, but many shade and ornamental trees are heavily damaged. Old or unhealthy trees are vulnerable, especially those previously weakened by repeated defoliation or by the Dutch elm disease.

Description. — The beetles are about a half-inch long. They are densely clothed with grayish fine soft hairs and have three orange oblique crossbars on the wing covers and a narrow orange stripe on the ridges of the thorax and the wing covers. The larvae are similar in general form to other round-headed borers; they are white, legless, and about 1 inch long when full grown.

Banded Ash Borer (See Key, 45)
(Neoclytus capraea)

Red-Headed Ash Borer (See Key, 45)
(Neoclytus acuminatus)

Hosts. — The ashes are the most important hosts, although numerous other tree species, including oak and hickory, are attacked.

Injury. — Dying trees are attacked, but the greatest damage is to logs left in the woods or to unseasoned logs stored in the millyard with the bark adhering. The early stage borers feed for several weeks under the bark, tunneling the surface of the wood (fig. 80, top). In the later stages they make galleries in the sapwood, especially the outer layers, completely honeycombing the wood and packing the galleries with granular frass (fig. 80, bottom). Generally the adults emerge the following spring; but when infested logs are sawed and the lumber allowed to season, development may be retarded and the adults will emerge at irregular intervals over a period of years.

Description. — Banded ash borer adults are dark brown beetles, about one-half inch long, with yellowish-white, irregularly shaped cross bands on the thorax and wingcovers. The red-headed ash borers are reddish-brown slender beetles, varying

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FIGURE 80. — *Top*, tunneling on the wood surface by the red-headed ash borer. (Photo courtesy Illinois Natural History Survey.) *Bottom*, banded ash borer galleries tightly packed with granular frass.

from one-fourth to three-fourths inch in length. They have yellow cross bands on the wingcovers, but none on the thorax. The larvae of the two species are very similar; they are dull white, rather hairy, and have minute thoracic legs. When full grown, they are one-half to three-fourths inch long.

Columbian Timber Beetle (See Key, 47)
(Corthylus columbianus)

Hosts. — Oak, maple, and birch.

Injury. — Tunneling in the sapwood of living trees by adults and larvae; the development of the ambrosial fungus causes a black stain, not only in the tunnels but also below and above (fig. 81, left). The trees are not killed, but the defect is permanent and the timber value is lowered. A closely related species, *punctatissimus*, has been reared from spiral galleries at the base of the stems in healthy silver maples in Minnesota; in 1960 it killed sugar maple and beech reproduction up to a height of 6 feet in Lower Michigan.

Description. — The tunnels are compound, each larva having its special gallery (fig. 81, right). The adults are shiny, dark brown, and about one-eighth inch long. The larvae are white, footless, and, when full grown, a little longer than the adults.

Ambrosia Beetles (See Key, 47)
(*Trypodendron* sp., *Xyleborus* sp., *Anisandrus* sp.)

Hosts. — Birch, oak, maple, and elm.

Injury. — Tunneling in the sapwood and heartwood by beetles and

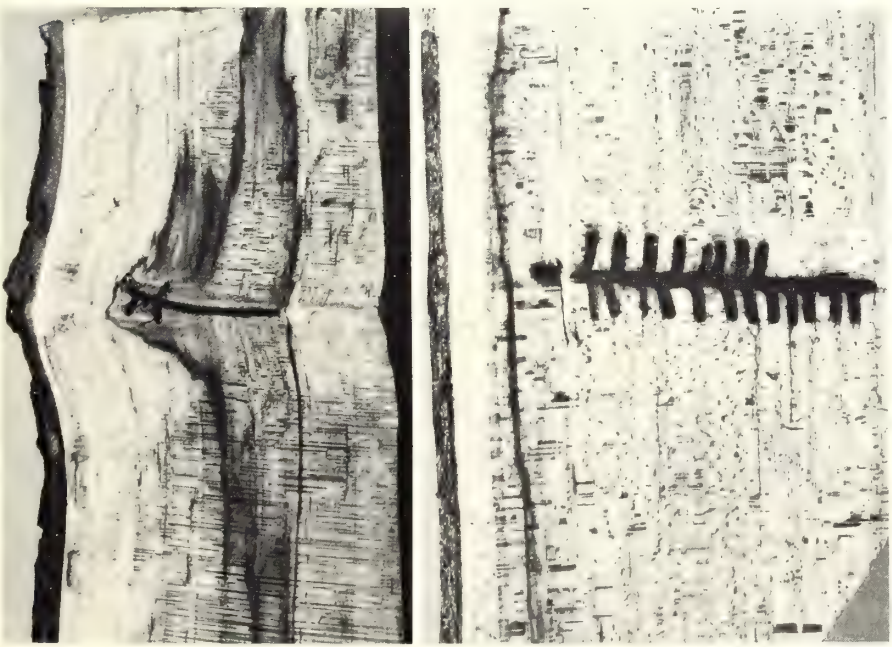

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FIGURE 81. — The black stained tunnels in white oak caused by the Columbian timber beetle. *Left*, slightly reduced. *Right*, slightly enlarged.

larvae, and the development of ambrosial fungus upon which the larvae feed. Although dying or recently cut trees are preferred, the attacks usually result in degrade of lumber and veneer stock.

Description. — The tunnels are compound; each larva has its special gallery branching from the main tunnel as shown in the diagrammatic drawing (fig. 82). They feed on ambrosial fungus brought to them by the adults. The larvae are white, footless, and, when full grown, one-eighth to one-quarter inch long, depending on the species. The adults are dark brown to black and slightly smaller than the full-grown larvae.

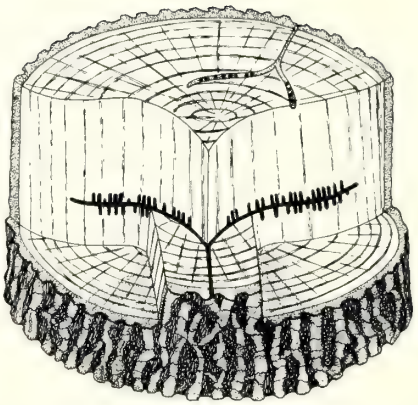

FIGURE 82. — Diagrammatic drawing showing typical ambrosia beetle tunnels. (Photo courtesy New York State University, College of Forestry, at Syracuse University.)

DISEASE VECTORS

A number of insect species are more important in their activities as vectors of tree diseases than they are as primary tree pests. Though these insects could be classified in the preceding groups, they are treated separately here to aid in identification.

Insects may be associated with tree diseases in many different ways. The insects, by their feeding or oviposition activities, may simply provide a means of entrance for the pathogen into the susceptible tissues of the tree. On the other hand, complex biological relationships may exist between the insect and the pathogen, resulting in their mutual benefit. To date, only a relatively few cases of insect-disease complexes are well understood. While these may not now be of especial importance on forest land in the Lake States, they are discussed in order to emphasize their potential danger.

Dutch Elm Disease

Smaller European Elm Bark Beetle
(Scolytus multistriatus)
Native Elm Bark Beetle
(Hylurgopinus rufipes)

Hosts. — All elm species except Siberian elm and Chinese elm.

Injury. — The lethal injury is the development of the Dutch elm disease in healthy trees through the feeding habits of the bark beetles. The beetles carry the fungus on their bodies and introduce the spores, principally at the twig axil, by chewing off the tender bark. Depending on the length of the growing season, there may be one to three generations annually. Of less importance than the smaller European elm bark beetle but still capable of transmitting the disease, is the native elm bark beetle. The presence of the disease can be first suspected when the foliage on a branch or the entire crown suddenly wilts. Confirmation can be obtained by sending insect or injury specimens

to your State Entomologist.

Description. — The adults of the introduced species are about one-eighth inch long, shiny, and dark reddish brown. There is a concavity and a long spine at the rear and lower part of the abdomen. The adults of the native species are also about one-eighth inch long, but are dull brown and do not have a concavity or spine at the rear of the abdomen. The larvae of the two species are very similar — white footless grubs, and, when full grown, about one-eighth inch long. For egg-laying, the beetles prefer recently cut, broken, or dying material. The egg galleries of the European species are usually straight and follow the grain of the wood; those of the native species usually consist of two branches and cross the grain.

Oak Wilt

Smaller Oak Bark Beetle
(Pseudopityophthorus minutissimus)

Hosts. — Oaks of the red oak group.

Injury. — Transmission of a wilt disease through the feeding activities of a small bark beetle. The beetles feed at twig crotches, at the base of leaf petioles, and in rough places on the bark. They breed in the outer sapwood of small stems and branches of dying and recently dead trees and also in logging slash. The first indication of the disease is foliage wilting — appearing as pale and curled leaves which later turn bronze or brown. Limb and bole sprouts may develop, but usually the affected trees die the same year. Transmission of the disease may also occur through root grafts. Confirmation can be obtained by sending specimens of the insect and the injury to your State Entomologist.

Description. — The adults are small, slender, reddish-brown bark beetles, slightly more than one-sixteenth inch long. The larvae are white footless grubs; and, when full grown, about one-sixteenth inch long. The egg galleries are cut across the grain.

Phloem Necrosis

Elm Leafhopper
(Scaphoideus luteolus)

Hosts. — American elm and its horticultural varieties — moline and vase.

Injury. — Injection of a virus disease into the tree through the foliage. The nymphs feed on the lower surface of the leaves, sucking out the plant juices and at the same time introducing the virus. The first indication of phloem necrosis is foliage wilting similar to that caused by the Dutch elm disease. Confirmation can be obtained by sending insects or injury specimens to your State Entomologist.

Description. — The adults are tawny-red leafhoppers with traces of white at the thorax, and are about three-sixteenths inch long. The nymphs are dark brown, with a white dorsal band on the front part of the abdomen.

SPECIES NOT YET REPORTED

Several species, not yet known to be present in the Lake States, have caused damage in the Northeastern States. Some of these are imported species, others are native. The beech scale, (*Cryptococcus fagi*), for example, and its associated nectria bark disease, have caused widespread mortality of beech throughout northern New England and the Maritime Provinces of Canada. A list would include such insects as the birch leaf-mining sawfly (*Heterarthrus nemoratus*), elm casebearer (*Coleophora limosipennella*), imported willow leaf beetle (*Plagiodera versicolora*), maple leaf cutter (*Paraclemensia acerifoliella*), and maple petiole borer (*Caulocampus acericaulis*).

During surveys and other forest work it will be advisable to collect suspected specimens of insects and their damage and have them identified.

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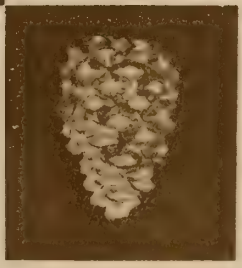
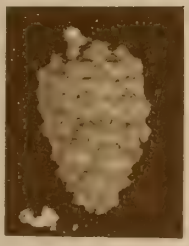
The Identification of Primary Red Pine Cone Insects





John S. Hard

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Contents

	Page
Introduction	1
A Key to Primary Red Pine Cone Insects by Mature Cone Damage Characteristics	3
A Key to the Mature Larvae Of Primary Red Pine Cone Insects	7
Relative Importance of Insects	9

Introduction

Red pine (*Pinus resinosa* Ait.) is one of the most important species used for reforestation in the Lake States. Because of the high cost and lack of control over genetic quality of commercially collected seed, the National Forest Administration has established seed-production areas in natural stands of trees with desirable lumber-producing characteristics. Since the objective is maximum production of high-quality seed, foresters are concerned with any agent that hinders this objective. One of the most destructive agents of cones and seeds is insects, despite the fact that damage is confined to the second year of cone development (fig. 1).

This guide will familiarize the forester or nurseryman in the Lake States with the damage caused by insects to red pine cones, and enable him to recognize the mature larvae of the various species and understand their relative importance.

Two separate keys are included. The first is based on damage to the mature cones. The second is based on mature larval characteristics, since it is possible that larvae of at least four species might still be in the cones at harvest time.

The keys are based on earlier work in Canada by Lyons[1] and on the author's experience with seed and cone insects in the Lake States. The diagnostic characters in the keys are primarily those used by Lyons because they are visible to the naked eye or with a hand lens. Also included is a chart (see fig. 15 at end of report) which shows when developing larvae of the various species may be found working in the cones.

There are other species of insects that inhabit red pine cones besides those mentioned in the keys. They are secondary species that do not create their own diagnostic damage symptoms and are of little importance. Those interested in more specific information on primary and secondary species are referred to Lyon's work.

The following definitions will aid readers unfamiliar with some of the terms used in the keys:

NOTE: The author is an Entomologist on the Station's Seed, Cone, Aspen, and Shelterbelt Insect Project. He is located at the Station's Headquarters building, which is maintained on the St. Paul Campus by the Forest Service, U.S. Department of Agriculture, in cooperation with the University of Minnesota.

[1] *Lyons, L. A. Insects affecting seed production in red pine. I. Conophthorus resinosae Hopk. (Coleoptera: Scolytidae). Canad. Ent. 88: 599-608, 1956. II. Dioryctria spp. (Lepidoptera: Phycitidae). Canad. Ent. 89: 70-79, 1957. III Eucosma monitorana, Laspeyresia toreuta Grt. (Lepidoptera: Olethreutidae); Rubsaamenia sp. (Diptera: Cecidomyiidae); and other insects. Canad. Ent. 89: 150-164, 1957. IV. Recognition and extent of damage to cones. Canad. Ent. 89: 264-271. 1957.*

F-506521

FIGURE 1. — A mature undamaged red pine cone.

Frass. — Fecal material.
Sub-dorsal. — Just below the center line of the back or top of the insect.
Seta. — A hairlike bristle.
Anal plate. — A hardened, shieldlike patch on the posterior end of the larva.
Thoracic segment. — One of the three body segments, immediately posterior to the head, which bear the segmented legs.
Sclerotized. — Hardened and usually pigmented.
Dorso-ventrally. — From top to bottom.

A Key to Primary Red Pine Cone Insects By Mature Cone Damage Characteristics

1. Cone with one or more holes in exterior 2
1. Cone free of holes in exterior 5
    2. Webbing and coarse fecal pellets attached to exterior of cone 3
    2. Exterior of cone free of debris 4
3. A single hole, approximately 1/16 to 3/32 inch in diameter, in side of cone near base; large cavity deep within cone containing some dried resin, fecal pellets, and webbing; scales on same side of cone as hole usually withered (fig. 2) .....*Dioryctria disclusa* Heinrich
3. One to several ragged holes in side of cone; extensive tunneling usually free of debris just beneath cone exterior; some internal webbing (fig. 3) ..*Dioryctria abietella* (D. and S.)[3]
    4. Groove at base of cone leading from hole in axis to outer margin of cone; round emergence holes often present in side of cone; axis mined longitudinally; seeds and scales destroyed; cavities in cone contain fine, granular frass; cone small and dead (fig. 4) .....The red pine cone beetle, *Conophthorus resinosae* Hopk.
    4. Numerous tiny holes in cone exterior or one or more larger oblong holes between scales in side of cone; extensive tunneling in seeds and scale tissue packed with a cementlike mixture of resin and frass; no webbing; longitudinal groove in cone axis; cone almost always dead (fig. 5) .....*Eucosma monitorana* Heinrich
5. Exterior of cone normal; limited tunneling in seeds and cone axis; tunnels empty but tightly packed debris in mined seeds (fig. 6) .....*Laspeyresia toreuta* Grote
5. Some cone scales dried and shrivelled; copious amounts of dried resin between shrivelled scales; no tunneling or debris present (fig. 7) .....*Rubsaamenia* sp.

---

[2] *Only one species, the red pine cone beetle, has an accepted common name.*

[3] *Or Dioryctria abietivorella (Grote) depending on authority. See Munroe, Eugene. Canadian species of Dioryctria Zeller (Lepidoptera: Pyralidae). Canad. Ent. 91: 65-72, 1959.*

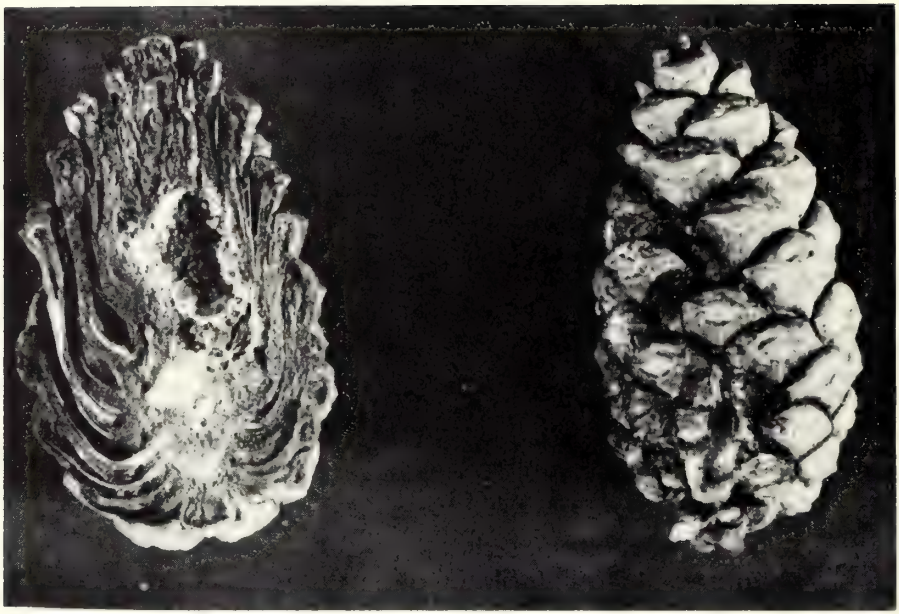

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FIGURE 2. — Cone infested by *Dioryctria disclusa*.

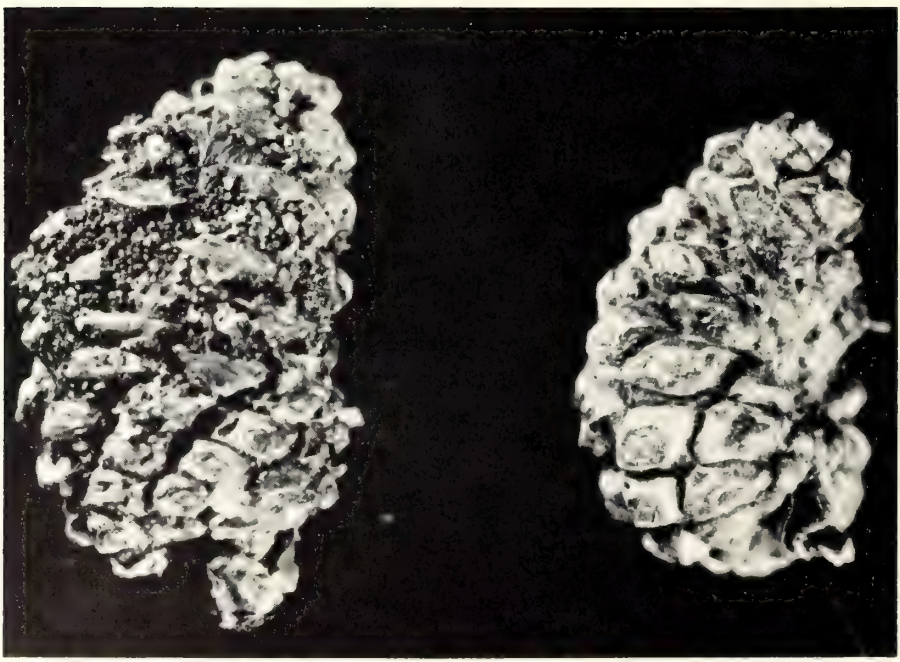

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FIGURE 3. — Cone infested by *Dioryctria abietella*.

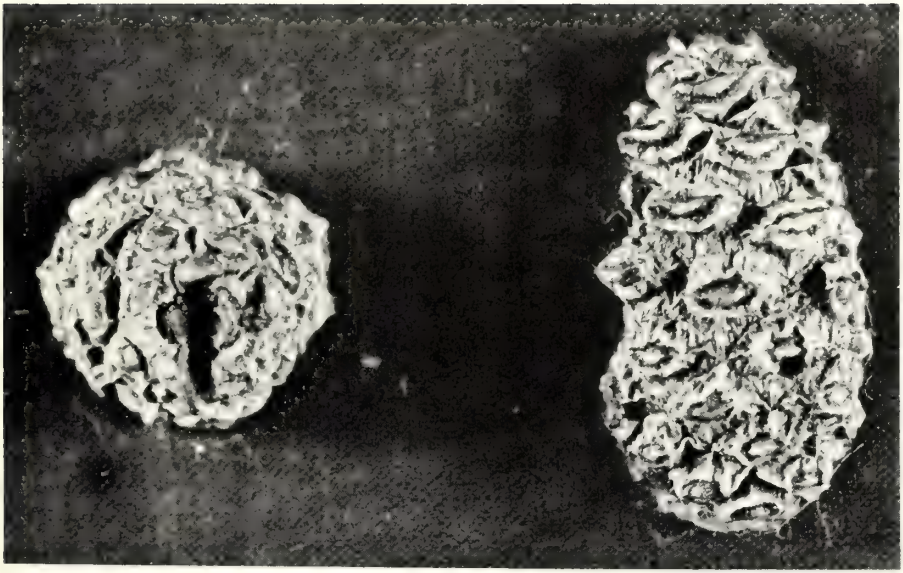

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FIGURE 4. — Cone infested by *Conophthorus resinosae*.

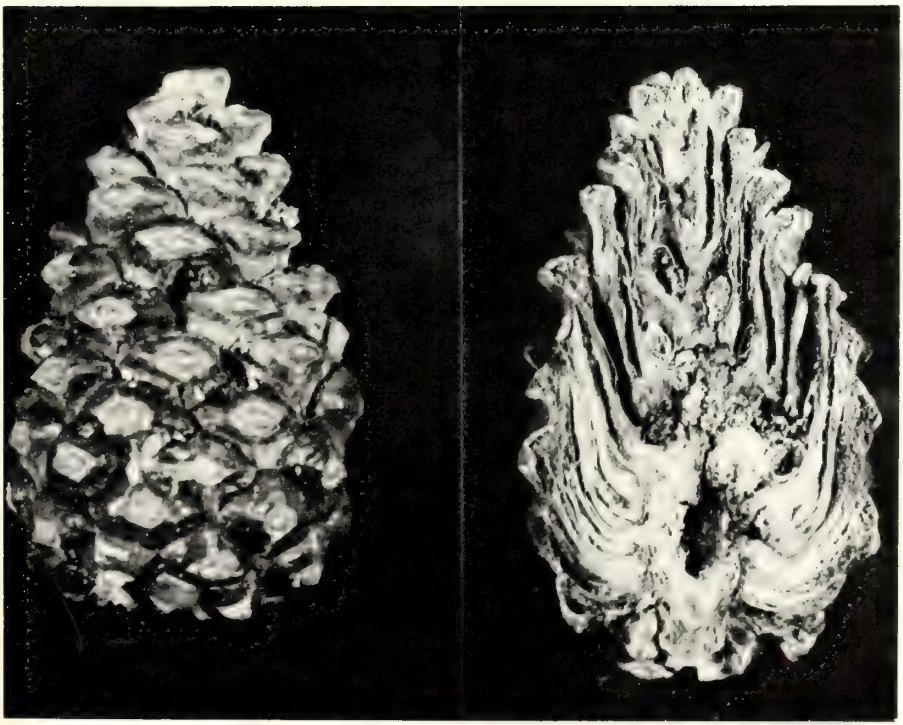

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FIGURE 5. — Cone infested by *Eucosma monitorana*.

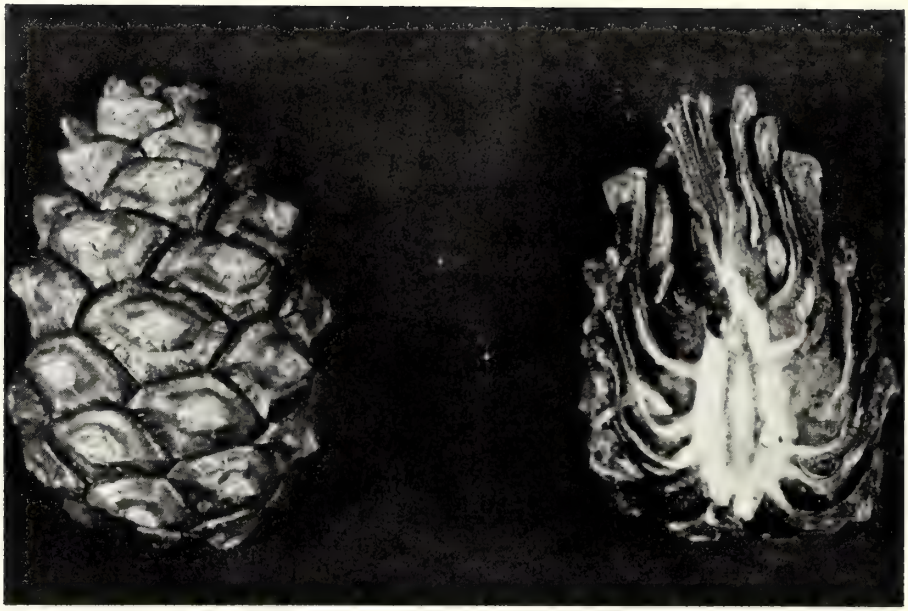

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FIGURE 6. — Cone infested by *Laspeyresia toreuta.*

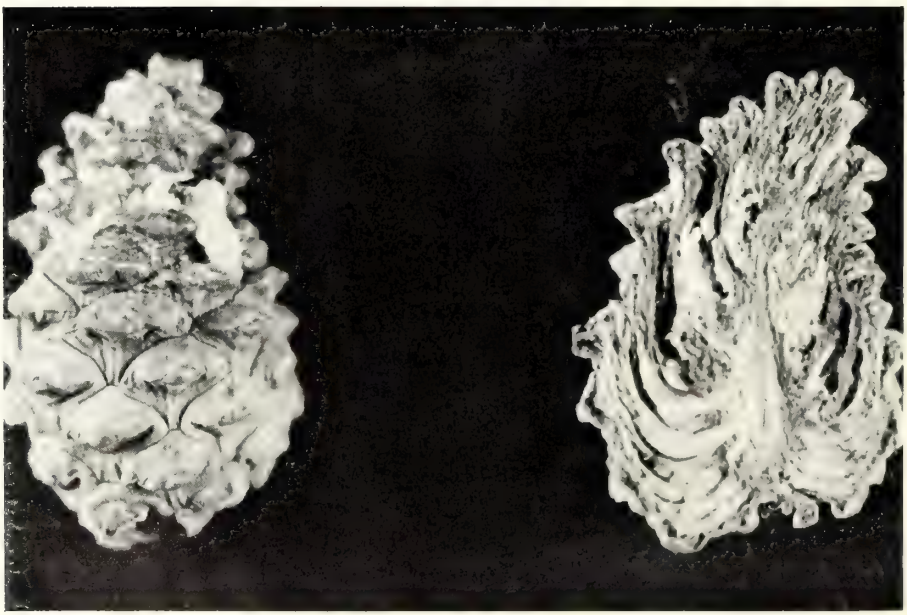

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FIGURE 7. — Cone infested by *Rubsaamenia* sp.

A Key to the Mature Larvae Of Primary Red Pine Cone Insects

1. Legs present; mature larvae usually occurring singly in a cone 2

1. Legs absent; several to many mature larvae per cone 5

2. Body longer than ½ inch; long sub-dorsal seta on second thoracic segment arising from a prominent sclerotized ring (fig. 8); body color variable but never white or near-white 3

2. One-half inch or less in length; head capsule brown; body color uniformly gray-white or creamy-white 4

3. Darkened lateral margins of anal plate (fig. 9); 5/8 to 1 inch in total length; body color dark green to reddish-purple ..... *Dioryctria abietella*

3. Uniformly pigmented anal plate (fig. 10); approximately 5/8 inch in total length; body color olive-green to purple-brown ..... *Dioryctria disclusa*

4. A dark spot within area bounded by simple eyes and another at rear of head capsule (fig. 11); setae on body easily visible with a hand lens; ½ inch in total length; body stout, gray-white ..... *Eucosma monitorana*

4. Thorax wider than partially retractable head (fig. 12); body devoid of easily visible setae; slightly less than ½ inch in total length; body slender, creamy white ..... *Laspeyresia toreuta*

5. Anterior end pointed; anal end with a pair of upward curved hooks (fig. 13); body flattened dorsoventrally; approximately 3/32 inch in total length; body reddish-orange and semi-transparent; usually many larvae per cone ..... *Rubsaamenia* sp.

5. Sclerotized light brown head capsule; body C-shaped and grublike (fig. 14); approximately 3/16 inch or less in total length; body color creamy-white; usually several larvae per cone ..... The red pine cone beetle, *Conophthorus resinosae*

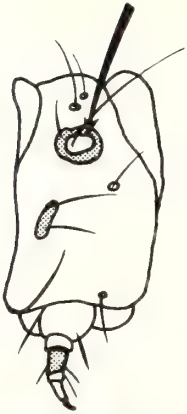

FIGURE 8
DIORYCTRIA SPP.; SECOND THORACIC SEGMENT; SIDE VIEW.

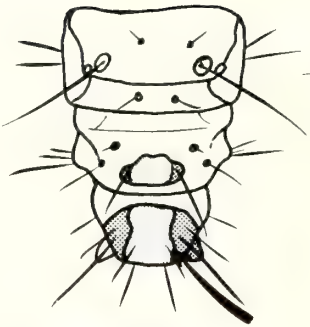

FIGURE 9
DIORYCTRIA ABIETELLA; ANAL SEGMENTS; DORSAL VIEW.

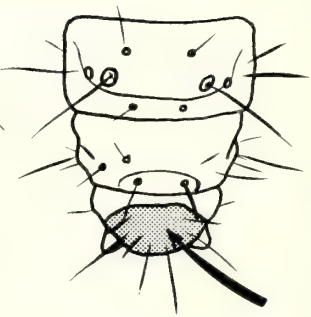

FIGURE 10
DIORYCTRIA DISCLUSA; ANAL SEGMENTS; DORSAL VIEW.

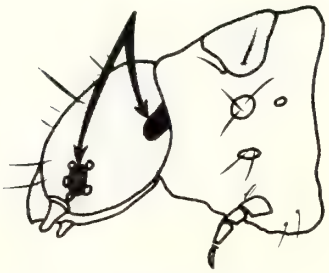

FIGURE 11
EUCOSMA MONITORANA; HEAD CAPSULE AND FIRST THORACIC SEGMENT; SIDE VIEW.

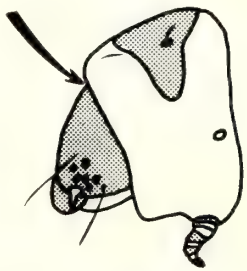

FIGURE 12
LASPEYRESIA TOREUTA; HEAD CAPSULE AND FIRST THORACIC SEGMENT; SIDE VIEW.

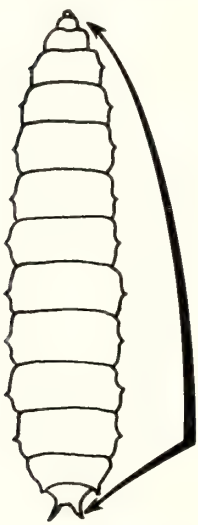

FIGURE 13
RUBSAAMENIA SP.; DORSAL VIEW.

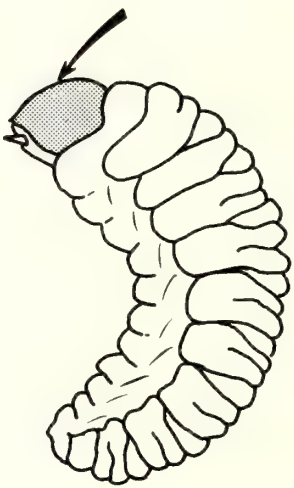

FIGURE 14
CONOPHTHORUS RESINOSAE; SIDE VIEW.

FIGURES 8 through 14. — Illustrating mature larval characteristics of the most important red pine cone insects.

Relative Importance of Insects

The insects discussed below are listed in order of the importance of their impact to individual cones; this order is constant. But when considering overall impact to a seed crop, the picture changes drastically and is variable from stand to stand and year to year.

Conophthorus resinosae. — Mining in the cone axis by the adult beetles for feeding or oviposition kills the cone, thus terminating development of the seed. When the population is extremely high, a portion is sometimes forced to breed in shoots, which destroys any developing conelets on the mined shoots. This species has been found in abundance throughout the Lake States.

Eucosma monitorana. — Individual larvae require two cones to complete development. Attack almost invariably kills both cones and terminates development of any seed that have not already been consumed. This species occurred infrequently in cone samples but has been reported as abundant in some stands in southern Wisconsin.

Dioryctria disclusa. — Early larval feeding is confined to male flowers until the time of pollen dissemination. However, individual mature larvae usually attack two cones before pupating. Since the larvae feed deep within the cone, some seeds are consumed. In addition, the cone axis is sometimes severed, resulting in death of the cone and remaining seed. This species occurred in moderate numbers in cone samples.

Dioryctria abietella. — Feeding by young larvae is confined to cones previously infested by other species. Individual mature larvae usually attack more than one cone, but feeding damage occurs near the cone exterior and some seed are released. This species occurred in moderate numbers in cone samples.

Rubsaamenia sp. — Larval feeding on surfaces between the cone scales causes a copious flow of resin and withering of the affected scales. These scales do not separate during normal cone opening, and their seeds are not released. This species occurred frequently in cone samples, and is often associated with damage by other species.

Laspeyresia toreuta. — Larval feeding is limited primarily to seed, but some escape attack. Since the cone scales are not affected, the cone opens normally and undamaged seeds are released. This species occurred infrequently in cone samples.

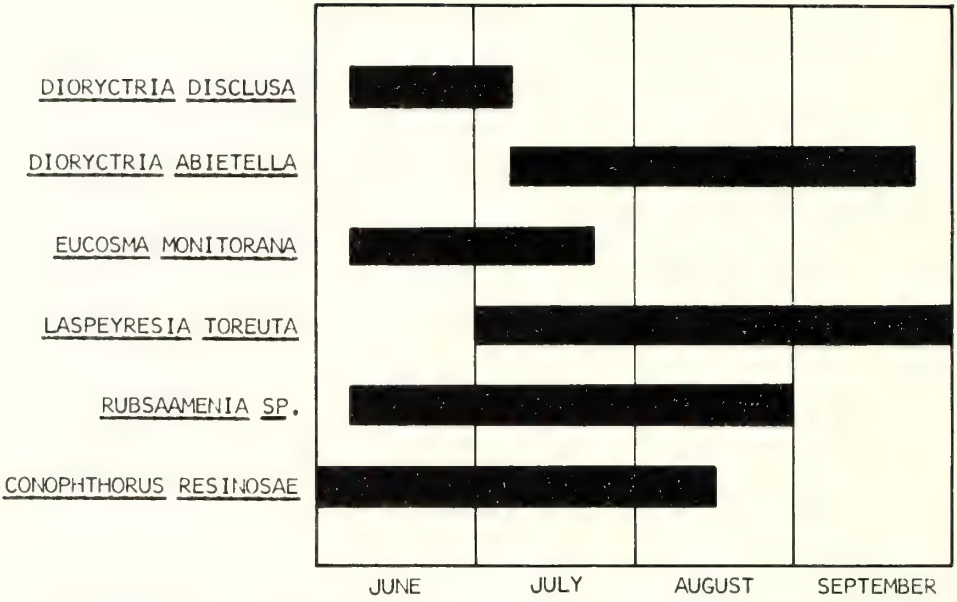

FIGURE 15. — Periods of larval occurrence in ripening red pine cones in the Lake States.

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Guide for Selecting Superior Trees for Shelterbelts in the Prairie Plains

David H. Dawson and Ralph A. Read

LAKE STATES FOREST EXPERIMENT STATION
M. B. Dickerman, Director
FOREST SERVICE
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August 1964

Guide for Selecting Superior Trees for Shelterbelts in the Prairie Plains

by
David H. Dawson
and
Ralph A. Read

LAKE STATES FOREST EXPERIMENT STATION
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CONTENTS

Page

ACKNOWLEDGMENTS ..... (Inside front cover)

INTRODUCTION 1

WHAT TO LOOK FOR 1
- Superior Stands 1
- Superior Trees 2
- Unusual Trees 2

HOW TO REPORT SUPERIOR TREES AND SHRUBS 2

WHERE AND WHEN TO LOOK FOR SUPERIOR TREES 4

SUPERIOR TREE CHARACTERISTICS 5
- Growth Rate 5
- Crown Formation 5
- Stem Form 6
- Soil Adaptation 6
- Phenological Characteristics 6
- Resistance to Drought 7
- Resistance to Winter Injury 7
- Resistance to Disease and Insect Attack 7
- Resistance to Damaging Wind and Other Detrimental Climatic Factors ... 7
- Seed Producing Capabilities 8

TRAITS OF IMPORTANCE IN PARTICULAR SPECIES 8
- Ponderosa Pine 8
- Eastern Redcedar and Rocky Mountain Redcedar 9
- White and Blue Spruces 10
- Arizona Cypress and Arborvitae 11
- Loblolly Pine and Shortleaf Pine 11
- Green Ash 13
- Cottonwoods and Poplars 13
- American Elm 14
- Siberian Elm 19
- *Ulmus* Hybrids 19
- Bur Oak 19
- Boxelder 21
- Other Tree Species 21
- Shrubs 21

LITERATURE CITED 22

INTRODUCTION

One of the major needs in Plains forestry, from the aspect of both research and field application of practices, is for genetically improved plant materials for use in wind barrier plantings.

It is commonly recognized that individual trees of the same species differ in observable characteristics. Some of the most obvious traits that seem to vary within a species are growth rate, color of foliage, size and density of foliage, angle of branching, width of crown, time of flushing and defoliation, straightness of stem, and resistance to drought, winter injury, insects, and disease. Some of the differences are due to site condition or to treatment after becoming established on that site, but some of the expressed traits are hereditary and will be passed on to progeny.

We need to seek out trees that manifest desirable traits so that we can bring about genetic improvement of the plant material used in shelterbelt plantings. We realize that some of the desirable traits of the superior phenotypes may not be inherited by their progeny, but others doubtless will.[1]

A program involving the selection of superior phenotypes will provide an immediate source of seed or vegetative material for production of nursery stock in the public and private nurseries. (Usually trees selected for this purpose will exhibit *several* traits which are "superior.") It will also serve to assemble phenotypes of both native and exotic species exhibiting one or more traits distinctly different than those exhibited by the bulk of the population. Such material may be very useful to research organizations for further testing and breeding purposes.

This publication defines some of the important desirable characteristics in shelterbelt species and thus provides a standard to aid in the selection of superior trees by field personnel interested in the tree improvement program. It is also intended to stimulate interest in the need for tree improvement among field technicians and encourage them to participate in locating superior plant materials.

Little research data have been collected concerning the most desirable traits for shelterbelt trees. There is a need for more information on the heritability of many traits as well as for more precise detection of these traits in the field. It may be a long time, however, before more precise criteria on these factors become available. In the meantime, considerable progress can be made by applying the knowledge we have. This interim guide has been prepared to summarize current knowledge and to help steer early efforts in a common direction.

WHAT TO LOOK FOR

The initial selection program for improving shelterbelt trees will involve a search for superior stands and seed sources, superior trees, and unusual trees.

Superior Stands

Within the Prairie-Plains region and in relatively dry areas adjacent to it are scattered stands of native trees. Some of these may consist largely of desirable trees and may be superior to other stands of the same species in the same general area. Despite the possibility that superiority may reflect unusually good growing conditions and thus may be largely an environmental effect, such stands should be selected and their progeny tested. In the meantime, they could well be used to provide seed for planting programs.

[1] *A superior or "plus" tree is one which in outward appearance is superior in one or more characteristics to the average tree of the same species growing on a similar site (Soc. Amer. Foresters 1958). Trees described on the basis of demonstrable characteristics are referred to as "phenotypes." Similar phenotypes do not necessarily breed alike. An individual tree's hereditary constitution, expressed or hidden, and underlying one or more characters is called a "genotype." It reacts with the environment to produce the "phenotype" (Snyder 1959). Names and dates in parentheses refer to Literature Cited at the end of this report.*

Planted stands (shelterbelts) are probably more widely distributed in the Prairie-Plains than are natural stands. Some of these shelterbelts may display uniformly good development of one or more tree species, and trees of such species should be selected and progeny tested. In some instances, the unusually good development or special resistance to some damaging agent may represent a particular race or seed source. Wherever possible, the original seed source of such plantings should be determined so that it can, if feasible, be used to provide seed for additional plantings.

Planting experience in other regions and countries has indicated that use of well-adapted seed sources is second in importance only to proper choice of species. Frequently certain varieties or races of a species are much better adapted physiologically to a given locality than are others. Some may also exhibit morphological differences. Therefore, seed from the sources producing the best adapted plants should be used in the planting program. This is as true for shelterbelts as for any other kind of plantation.

When information is lacking as to what seed source or sources would probably be most desirable, seed should be collected from a region as similar as possible to the proposed planting sites in growing season, frequencies of summer droughts, other environmental conditions, and latitude.

A continuing research program is underway to test the adaptability of different geographic sources of native and exotic tree species for shelterbelt use. Initially, this research must determine the presence of races[2] in these species, means of readily identifying them, and their ranges of distribution.

Superior Trees

Forest stands and plantations frequently contain trees that differ in certain characteristics from the average of the stand. An examination of any stand of trees probably will reveal about as many trees above average as below average in such important traits as angle of branching, height development, straightness of stem, crown density, live branch retention, and resistance to drought, insects, and disease. An early and necessary step in the tree improvement program is to select those trees distinctly above average (superior) in such characteristics as are desirable for shelterbelt trees. Probably most trees selected will be superior in only one or a few of the important traits, but it is important to find and utilize them.

Unusual Trees

Some trees exhibit characteristics very different than the bulk of the species. Such traits can be extremely slow terminal growth (in relation to lateral growth), causing the "mound" type of habit; extremely acute branch angle, causing a fastigiate growth form; bark or foliage characteristics entirely different than is typical for the species; or a demonstrated adaptation to a geographic area outside the usual range of the species. Trees having such traits may be peculiarly adapted races, mutations, or natural hybrids. Although their traits may not be especially desirable in shelterbelt species, such trees may be valuable as possible genotypes to use in a breeding program and should be reported.

HOW TO REPORT SUPERIOR TREES AND SHRUBS

When individual trees or stands of trees are found which would seem to meet the standards of superior or unusual trees discussed in this guide, they should be reported to the Shelterbelt Laboratory, Lake States Forest Experiment Station, Bottineau, N. Dak., or Rocky Mountain Forest and Range Experiment Station, 110 Plant Industry Bldg., Agriculture College, Lincoln, Neb. A card form of the "Superior Tree Report" shown on the next page is available for reporting purposes.

It is unlikely that any one tree will be found that is superior in all traits, but trees that are outstanding in any of the traits listed below should be reported:

A. *Report trees having any one of the next eight items.*
   1. Growth rate: Trees notably superior in height or diameter.
   2. Crown development: Good foliage reten-

[2] *In some instances variation doubtless will be found to be continuous (clinal) and not subject to delimitation by boundaries. It may still be possible, even in that event, to determine that seed should be collected within a given territory or zone for best results in a given locality.*

Superior Tree Report

Species of Tree (or stand): _____ Date _____

Location: "40" _____ Section _____ T. _____ R. _____

County _____ State _____

Owned by: _____

_____

(Drainage, roads, trails, other landmarks)

_____

_____

Reason for selecting the superior tree or stand. Check the main outstanding qualities:

Growth rate _____ Health and Vigor _____

Crown Development _____ Branch Development _____

Stem Form _____ Seed Production _____

Resistance to: Weather Injury _____ Insects _____

Diseases _____ Animal Damage _____

Other _____

Size and age of tree or trees: Total height _____ feet;

dbh _____ inches; age _____ years.

Native source of seed (if known) _____

Other information and remarks: _____

_____

_____

Reporter: Name _____

Address _____

_____

tion, uniform density, moderately broad crowns.

3. Branch development: Good live branch retention; uniform, dense branching habit.
4. Weather injury: Resistance to drought, flooding, cold, sleet, heavy snows, strong wind.
5. Insect damage: Resistance to insect pests affecting the species.
6. Diseases: Resistance to diseases affecting the species.

B. *Report any trees showing unusual development such as:*

7. Dwarf form, fastigiate branching, other extraordinary branching habits.

C. *Report exceptionally good stands, plantations, or shelterbelts composed chiefly of:*

8. Trees of good form, size, and quality. (Plantations and belts should be at least 5 years old.)

Cooperation in reporting SUPERIOR TREES or STANDS will be greatly appreciated. The reports will be checked by U.S. Forest Service Experiment Station staff members attached to the Forest Experiment Field Station located nearest the trees reported. Trees that they consider promising will be evaluated by specialists in forest genetics. The trees passing this examination will be used in breeding programs aimed at developing better forest trees for the Plains. Careful reporting of potential superior trees can contribute substantially to this program.

WHERE AND WHEN TO LOOK FOR SUPERIOR TREES

The Prairie Plains offers a large variety of plant material from which to select superior phenotypes for shelterbelts. Although the naturally forested area in the region is small, there is a considerable amount and variety of woody material, some of which probably represents superior genotypes.

Some of the best sites for selection of superior phenotypes are the shelterbelts 20 or more years old. In many of these plantings a selection process took place in the collection of seed, seedlings, or clonal material. A further selection took place in the nursery and in grading before planting. On site, natural selection has been at work since the trees were planted. As these trees grow larger, the differences in growth characteristics between trees of the same species in the same or different shelterbelts become more obvious. It is not surprising that there is considerable genetic variation among the trees due to the many sources of planting stock used in these plantings. Between 1935 and 1942 alone, a total of 200 million trees and shrubs from many different seed sources were planted in the Great Plains (Read 1958). This variety of material, plus that planted in earlier years, provides an excellent source from which to select superior phenotypes.

Plantations of trees of known seed sources — such as those at the Denbigh Experimental Forest at Denbigh, N. Dak., the Nebraska National Forest at Halsey, Nebr., and Agricultural Research Service Field Stations at Woodward, Okla., and Mandan, N. Dak. — can be excellent sources of superior trees. The performance of these trees from known seed sources under the relatively uniform conditions is a good indication of genotypic characteristics.

In some of the plantations and shelterbelts where mortality of some species and selections is very high, the remaining few trees may be highly desirable variants of the population (Nienstaedt 1960). These trees should be tested to determine if the apparent variance is truly adaptive.

In natural stands throughout the Plains are many of the species of trees and shrubs that are being used extensively in shelterbelts. Species in natural stands that have proven of value are eastern cottonwood, American elm, boxelder, green ash, eastern redcedar, and ponderosa pine. Others such as black cherry, bur oak, and hackberry offer possibilities not fully explored.

Most tree species that cover a wide geographic range consist of a varying number of geographic races that have become adjusted through centuries of natural selection to the various environmental regimes occurring within the range of the species (Kramer and Kozlowski 1960). Phenotypically superior individuals — or stands — can be recognized among these woodlands.

In addition to the natural stands within the area itself, there are, near the borders, "outliers" or disjunct stands of species found in abundance east or west of the Plains area. These trees may prove to be races that are peculiarly adaptive to the environment of the Plains. These stands — sometimes considered "relict" (Potter 1952) — offer considerable opportunity for individual tree selection. Seed source studies to determine variation and relative adaptability to plains conditions are recommended.

Selection for certain traits can take place only at specific times or under certain conditions. Periods following heavy insect infestations, disease epidemics, and climatic extremes such as droughts, ice storms, early or late frosts, and extremely high or low temperatures can be particularly rewarding in selection for resistance to normally injurious agents. The readily discernible effects of some of the agents may be delayed for a considerable time after the tree has been exposed to them, so selection usually should be delayed for a month or more after exposure.

All the traits of a tree are determined to some degree by its genetic makeup, although many of these traits are modified by the environment in which the tree is growing: soil, light, climate, other plant and animal life. Although the exact extent to which these traits are influenced by environment is not known, the following characteristics are generally believed to be heritable:

1. Growth rate (diameter and height)
2. Crown formation
   a. Shape
   b. Density
   c. Size of lateral branches
   d. Retention of live branches
   e. Angle of branching
3. Stem form
4. Soil adaptation
5. Phenological characteristics
6. Resistance to drought
7. Resistance to winter injury
8. Resistance to disease and insect attack
9. Resistance to damaging wind and other detrimental climatic factors
10. Seed-producing capabilities

The complete evaluation of these traits requires much research. But an active program on genetic improvement of shelterbelt planting material for the Great Plains should be started without further delay. It is recommended, therefore, that an active program of selection begin now. This guide can serve as a basis for such a program until better, research-tested methods become available.

Growth Rate

The growth rate or vigor of a tree is expressed largely in its height and diameter growth. *Height is the best, most heritable indicator of vigor,* whereas diameter is much more influenced by environment.

Height is especially important because it contributes substantially to a shelterbelt's effectiveness. Both the rate of growth and the maximum attainable height, compared to the majority of the species population, should be considered.

Extremely rapid growth is frequently a factor contributing to weak wood. All rapid-growing trees should be progeny-tested, however, as some may have wood stronger than average. Furthermore, such trees may be useful in a breeding program to combine rapid growth with strength.

Although diameter growth is not strongly inherited, trees outstanding in this trait should be reported.

The growth rate can be reflected in very young trees, and although undesirable traits present in these young selections can show up later, juvenile vigor is important in shelterbelt species and should be recognized. Seedlings in nursery beds sometimes reflect an inherent vigor and can be selected for further testing. Seedlings for the production of planting stock should not be selected, however, exclusively on the basis of performance in the seedling bed.

Crown Formation

The relative height, width, length, shape, and density of the crown are important in the selection of trees for windbreaks, for these traits largely determine the effectiveness of the wind barrier.

However, the progeny of selected trees will be used as components of many different forms of windbreaks. The windbreaks will vary in structure from one to several rows planted at various spacings. They will vary in orientation from north and south to east and west. They will also be designed and planted to serve different primary purposes such as soil erosion control, snow distribution, or livestock and dwelling protection.

Adding to the problems of the various patterns of windbreak structure and orientation and the purposes for which they are used, the optimum density (or porosity) of a shelterbelt for maximum soil erosion protection or for most uniform snow distribution over the cropland has not been scientifically determined (George 1960).

Caborn (1960), in discussing the influence of density as a factor in shelterbelt efficiency, has stated:

> "On the basis of experiments involving artificial windbreaks in the open and model screens in wind tunnels, it is now recommended that the optimum degree of penetrability to the wind or 'porosity' for a shelterbelt is approximately

40%. Clearly this moderate penetrability as applied to living structures in the field can only be found empirically, but shelterbelts of medium density with no large gaps and a uniform structure all the way to the crown level, would appear to fit this category."

He further states, "No evidence has been forthcoming to substantiate the view that a belt should be more permeable in its lower parts than in the crown space."

Therefore, to fulfill the majority of needs for shelterbelts, those trees with a high degree of foliage production, good live branch retention, and a uniform density should be selected.

Variation in the width or broadness of crown should be noted. Generally, trees with moderately broad crowns are most desirable; however, the tendency for apical dominance and strength of branches should not be sacrificed.

Density is determined by component factors of angle of branching, thickness of branches, number of branches, live branch retention, and kind and amount of foliage. The density of the crown may be judged in field observations for reporting purposes with a subjective rating of dense, medium, or sparse. (See later illustrations for individual species.) Because wind protection is essential during the entire year, the density of deciduous trees is best evaluated when the trees are without foliage. Foliage production, however, does contribute to summer density and is also a factor to consider. On deciduous trees, the size of leaves and the degree to which foliage is retained in fall could be significant characteristics in tree selection. In coniferous trees, foliage production, years of needle retention, and relative needle length are extremely influential in establishing a density rating.

Stem Form

Stem form is very important in selecting trees for timber production and less important in selecting trees for windbreaks. A windbreak composed of straight trees would conceivably have more even density than one in which crooked trees were used. Also, in view of the mass of wood being produced by trees in shelterbelts, those specimens that exhibit a desirable stem form for wood production should be preferred, but trees with slightly crooked stems that manifest other *plus* characteristics should also be included in selection. Forked trees are undesirable.

Soil Adaptation

The shelterbelt program in the Plains is in need of trees that are adaptable to alkaline and saline soil conditions. The best evidence of individual trees that can withstand alkalinity or salinity is in shelterbelts and natural stands growing in these soil conditions. Specimens that have survived and remained vigorous probably have a high degree of adaptability to a wide range of soil conditions or are physiologically suited to alkaline or saline soils.

Phenological Characteristics

Although the time of flushing and of maturing current growth is important as a factor in a tree's ability to withstand climatic extremes, the number of months a tree maintains foliage directly affects its ability to act as a wind barrier. Generally, with deciduous trees, the longer the foliage is on the tree, the better the wind protection it can be expected to give. In selecting for this trait, however, consideration should be given to the fact that more severe cold damage may occur to those selections exhibiting this trait.

Late spring frosts often kill back shoots. A sudden drop in temperature may kill back leaves, buds, twigs, and whole branches if tissues are not dormant. Resistance to this damage is generally related to the time of flushing. Those individuals that exhibit a slower rate of bud advancement in the spring or normally break dormancy later than the majority of the species are more apt to be resistant to spring frost damage (Kramer and Kozlowski 1960).

Late spring frost damage can be recognized by dead tips on branches, flower and foliage buds killed, and roots damaged. Conversely, superior phenotypes may be indicated by growth to tips of branches, regular seed production, and maintenance of general vigor.

Frosts in the late summer or early fall, occurring before the tree has entered its dormant period, can also cause severe injury or death. Most temperate zone trees can withstand winter temperatures as low as --50° C. However, the same trees are killed by temperatures slightly below freezing if they are artificially frozen in midsummer (Kramer and Kozlowski 1960). One of the traits related to resistance to early fall frosts is the early maturing of wood (Baxter 1952).

Resistance to Drought

Although precipitation is normally sufficient for the survival and growth of well-chosen and well-managed trees in shelterbelts, certain years of extreme drought have been very detrimental to tree growth and survival (George 1936).

Drought-injured trees die from the top down and from the exposed side inward, but in conifers this symptom may not always be evident because of unequal drying of needles (Baxter 1952). In deciduous species, the leaves turn yellow or reddish, beginning at or near the leaf margins or occasionally midway between the main veins until finally the entire leaf is involved (Boyce 1938).

Trees being judged on their ability to survive drought should be compared with others of their species at the same location, having the same exposure or protection, to eliminate microclimatic and ecological differences. Because trees utilize subsoil moisture, selection should be made not only the year of the drought, but the year after, as drought injury is frequently manifested the second year.

A large number of physiological and morphological characteristics contribute to a tree's ability to withstand periodic droughts. Some of these characteristics are: depth and nature of rooting system, transpiration rate, size of foliage (length of needles on conifers), stomata arrangement and density, and cuticle thickness on foliage. The determination of superiority in these characteristics demands detailed measurements and tests. Progeny tests are necessary to determine the degree of inheritance of these traits.

Resistance to Winter Injury

Injury traceable directly to effects of low temperatures or to desiccation during the cold months of the year may affect tissues above and below ground (Kramer and Kozlowski 1960).

The more widely recognized forms of winter injury include killing back of shoots, frost cracks, "needle burning" of conifers, winter sunscald, cambial injury, and root injury. Individual trees or races vary in their resistance to winter injury.

Winter injury is manifested quite frequently in the Great Plains coniferous species by browning of foliage upon the advent of warm weather in the spring. With severe injury, all the needles and buds are killed and the trees die. More commonly, the older needles are affected the most. Frequently, however, even though all the needles are killed, the buds escape and the trees survive.

The resistance of a particular phenotype to all forms of winter injury is a significant factor in tree improvement work for the Great Plains. Trees should be compared with their immediate neighbors in spring to determine any resistance they might have. Winter injury is usually fairly obvious. Comparisons with other trees of the same species and seed origin should be made on the same sites, as site conditions greatly influence the degree of winter injury a tree may suffer.

Resistance to Disease and Insect Attack

To survive and be effective, windbreak trees must be resistant to diseases and insect attacks. Yet such trees are particularly vulnerable to such injury.

Although the species used in Plains shelterbelts are the ones best adapted to the growing conditions, most of them do not fare as well as in their native habitat. Because of the adverse environmental conditions, such as lack of sufficient rainfall, severe winters, and alkaline soils, tree vigor is frequently reduced (Wilson 1962). Furthermore, many shelterbelts are composed of one or only a few rows of trees, and such a belt can easily lose its effectiveness as a result of a single insect attack (Wilson 1962).

It is possible that individuals of shelterbelt species can be found that are relatively free from an insect or disease that is damaging neighbors of the same species. No one individual or race is likely to be resistant to all diseases and insects which at times attack the species, but it is not unusual to find individuals resistant to a particular disease or insect.

Resistance to Damaging Wind and Other Detrimental Climatic Factors

Local wind, hail, sleet, and heavy snow storms damage trees noticeably. It is likely that certain individuals will exhibit much less storm damage than their neighbors of the same species. These trees may be genetically superior in their ability to withstand such adverse conditions.

Seed Producing Capabilities

Seed production does not contribute directly to the effectiveness of a shelterbelt. However, it should be considered as a desirable trait in a tree that also has other superior characteristics because reproduction of most superior trees will be from seed.

Frequently, decadent or damaged trees produce large quantities of seed. Such trees should not be chosen if they are inferior in other traits.

TRAITS OF IMPORTANCE IN PARTICULAR SPECIES

In addition to the traits described that may be indicative of genetic superiority in all species, there are special traits to look for in individual species. Some of these are listed on the following pages.

Ponderosa Pine

Ponderosa pine (*Pinus ponderosa* Laws) for use in the Plains area should be selected for superior vigor, drought resistance, resistance to winter injury (needle browning), needle retention, broad, dense symmetrical crowns, and above-average live branch retention. Trees should be selected for resistance to damage from tip moth (*Rhyacionia* spp.), Black Hills beetle (*Dendroctonus ponderosae*), and sawflies (*Neodiprion* spp.). Trees resistant to root and butt rot (*Fomes annosus*) and blister rust (*Cronartium* spp.) particularly, should be sought (Curtis and Lynch 1957). Because there have been considerable difficulties in establishing field plantings, it would be well to report seed sources (if known) of planting stock that established unusually well (figs. 1-5).

F-506423

FIGURE 1. — A phenotype of ponderosa pine desirable for shelterbelt planting. This tree is growing in a 25-year-old plantation. Note the medium, uniform density, high degree of live branch retention, full, relatively broad crown, good rate of height growth without spindliness, and good seed production.

F-506424

FIGURE 2. — Phenotypes of ponderosa pine in a natural outlier in Nebraska, showing variability of crown forms. The fastigiate form on the left of the group is of particular interest for breeding, but one of the wider crowned forms would be better for shelterbelts. Note the differences in branch retention characteristics.

F-493112

FIGURE 3. — Two ponderosa pine trees with different characteristics growing in a shelterbelt. Although the tree on the left is taller, it has a sparse, narrow crown and exhibits poor branch and needle retention. The tree on the right is better suited for shelterbelt use because it has a medium-broad crown, medium density, and superior live branch retention.

F-486519

FIGURE 4. — Ponderosa pine in a 67-year-old stand in northeastern Nebraska. This stand has proved its ability to survive under severe Plains conditions. The sweep in lower branches may be an inherited characteristic. Crown form of the tree in the foreground is good for shelterbelts.

Eastern Redcedar and Rocky Mountain Redcedar

Eastern redcedar (*Juniperus virginiana* L.) and Rocky Mountain redcedar (*Juniperus scopulorum* Sarg.) have been used with a high degree of success in the Plains States (George 1953, Read 1958). They could be even more valuable trees for shelterbelts if they grew taller.

There is a pronounced racial variation within these species (Williamson 1957).

Phenotypes should be selected for superior height growth in the Northern Great Plains conditions, for variations in the usually very dense crown development, and resistance to winter burn (figs. 6, 7).

F-506425

FIGURE 5. — Ponderosa pine in a 25-year-old shelterbelt. The two trees indicated by arrows have superior characteristics. The tree on the right exhibits superior height growth, a straight stem, uniform medium density, and has a medium-broad crown. A greater crown density and a higher degree of live branch retention would be desirable. The tree on the left shows better-than-average height growth and has a desirable broad, dense crown.

F-502141
FIGURE 6. — The tree indicated on the left in this redcedar windbreak is desirable for shelterbelt planting because it has a broad crown (particularly near the top of the tree) and even density and because it is taller than the other trees in the belt.

White and Blue Spruces

White spruce (*Picea glauca* (Moench) Voss) and blue spruce (*P. pungens* Engelm.) have been used extensively in shelterbelts on all but the most arid sites in the Northern Great Plains. George (1953) reports that these species at Mandan formed effective shelterbelts but that they should be used on only the more favorable moisture situations. Spruces are difficult to establish in dry seasons.

Superior phenotypes of spruce are undoubtedly present, although little is known about the racial variation, particularly in *P. glauca* (Nienstaedt 1957).

Superior spruce trees should be selected for uniform density. Because of their greater density compared with some other shelterbelt species, both phenotypes that are sparse *and* those that are dense should be selected.

Identification and isolation of races resistant to drought and winter injury would enlarge the practical range of spruce species.

Although there have been few insect and disease enemies of spruces reported in the Plains area, *cytospora* canker does affect some blue spruce trees, and phenotypes evidencing resistance should be chosen (figs. 8-10).

F-506426, 27
FIGURE 7. — Two common growth forms of Rocky Mountain juniper. The short, multiple - stemmed type represented by the specimen on the left normally would not attain the height growth of the type represented by the straight, single-stemmed specimen on the right. Unless progeny are to be used for a dense shrub row in a shelterbelt, selections should be made from the single-stemmed type.

Arizona Cypress and Arborvitae

The Arizona cypress (*Cupressus arizonica*) and arborvitae (*Thuja* spp.) hold great promise for use in windbreaks in the southern Plains (Kansas and southward). Both species function well as dense lower and middle-level components with greater drought hardiness and longevity than most broadleaf trees.

E. W. Johnson, at the Agriculture Research Service Field Station at Woodward, Okla., has already done some selection in both species; the results appear much superior to the general run of stock. Further selection is needed for certain types of crown form and adaptive traits for soils in Southern Plains (fig. 11).

Loblolly Pine and Shortleaf Pine

The loblolly (*Pinus taeda* L.) and shortleaf (P. *echinata* Mill.) southern pines have been used in Plains windbreaks in Oklahoma, Kansas, and Texas. Both species offer exceptional promise as the tall, long-lived component of field windbreaks. The average total height of loblolly pine near Vernon, Texas, at 20 years of age was 26 feet.

If improved materials of these species are developed especially for the Plains, their use in windbreaks would doubtless increase. One of the major problems has been in securing adequate initial survival. Stock selected for juvenile vigor and rapid root growth could help solve this problem.

Selection of drought resistant sources should follow the example set by Zobel, Cech, and Goddard in Texas in which Lost Pines loblolly (130

F-506428

FIGURE 8. — A phenotype of spruce more desirable than most of the species for shelterbelt usage. Note the somewhat rounded, full crown, a tendency toward the columnar growth form, and the uniform density.

F-506429

FIGURE 9. — Twenty-five-year-old spruce in a roadside planting. Note the less pyramidal crown form and more uniform density of those trees marked with arrows. These are a more desirable shelterbelt type.

F-506430

FIGURE 10. — An unusual phenotype of blue spruce at Denbigh, N. Dak. This tree is of interest to the tree breeder because of its accelerated lateral growth in comparison to the terminal growth, resulting in a broad rounded form. It is possible these growth characteristics could be transmitted to progeny. This tree is about half the height of its neighbors. The poor height growth would make it undesirable for shelterbelt use.

miles west of the main distribution) was proved to be superior in drought resistance to more eastern sources (Zobel 1955).

Sources of these two pines should be screened not only for drought hardiness but also for resistance to stem rust and needle cast diseases and tip moth damage. Great variation in crown form can be expected, and selection for Plains material might emphasize crowns of greater density than the general run of southern pine phenotypes.

F-486494

FIGURE 11. — A shelterbelt of Arizona cypress showing variation in height growth and crown development. The taller trees that are maintaining good crown density near the top (as shown by arrows) are most desirable.

Green Ash

Because of the extensive natural range of green ash (*Fraxinus pennsylvanica* Marsh) (Meuli and Shirley 1937), there are likely many different races, some of which probably have superior traits for shelterbelts (Wright 1944). It has been found experimentally that progeny from local seed sources, in general, have been more drought resistant and better adapted to Plains conditions than those from moister regions (Meuli and Shirley 1937, U.S. Forest Service 1937).

The very satisfactory performance of green ash in the shelterbelt program (Read 1958) indicates that the selection of superior phenotypes is well justified in this species. Trees should be sought that are above average in growth rate, drought resistance, straightness of stem, and broadness and density of crowns. A high degree of live branch retention is desirable. Resistance to insect attacks, particularly ash borers (*Podosesia fraxini*), is important. Trees that, when compared to the majority of the species, flush early in spring and retain foliage late in fall are desirable (figs. 12-15).

Cottonwoods and Poplars

Several species, varieties, and hybrids of the *Populus* genus are being used extensively in the Prairie Plains shelterbelt program, particularly in those areas in the eastern part of the zone where effective precipitation and depth of water table are more favorable for their growth.

Vast differences in the growth, form, vigor, crown development, and resistance to disease, insects, drought, and winter injury occur among members of the *Populus* genus.

F-506431

FIGURE 12. — A desirable form of young green ash exhibiting greater-than-average crown density, straightness of stem, good branch retention, and superior growth rate.

F-295456

FIGURE 13. — A natural stand of green ash exhibiting poor form. Note the forked trunks, sparse crown density, poor vigor, and poor branch retention. These trees have shown their ability to survive under Plains conditions, but otherwise they are not desirable types for shelterbelt use.

F-500510

FIGURE 14. — Green ash in a 17-year-old shelterbelt exhibiting good crown density, good live branch retention, and good growth rate. The slight sweep in the trunk of the tree in the foreground is not too undesirable, but the forking in trees in the background should eliminate them from selection.

F-295457

FIGURE 15. — A native stand of green ash. Although the tree in the foreground has a slight sweep in the trunk, it is straighter than most other trees in the stand. The growth rate appears superior. Greater crown density and better live branch retention would make it more desirable for shelterbelt purposes.

Superior trees of this genus would manifest such traits as (figs. 16-20):

- Resistance to canker, scab diseases, and leaf rust.
- Tall, straight trunks.
- Dense, relatively fine branching habit with good branch retention.
- Resistance to breakage from ice and wind.
- Adaptability to alkaline soils.
- Above-average adaptability to low water table sites.
- Above-average longevity.
- Superior vigor.

American Elm

The native American elm (*Ulmus americana* L.) have survived quite well throughout the region in shelterbelt tests (Read 1958). Its weakness seems to be an inability to withstand severe drought during extended dry periods, particularly on shallow upland soils (George 1936, Read 1958).

American elm should be selected for drought resistance, growth rate, a tendency toward a horizontal angle of branching, better-than-average branch retention, and dense crowns.

Wilson (1962) reports heavy woolly elm aphid and elm sawfly infestations in the Northern Plains. In years of heavy infestation, phenotypes appearing to be resistant or recovering vigorously from damage should be selected.

Dutch elm disease is a serious problem in the Southern Plains and may well spread to other sectors eventually. Any individuals showing resistance to the disease should be noted (figs. 21-23).

F-506432

FIGURE 16. — Thirty-year-old cottonwood trees. The tree on the left has a medium-dense crown, straight stem, good height growth, and good live branch retention. The tree on the right has a narrow crown, inferior growth rate, and less dense branch habit. The tree on the left is preferred, but even greater crown density would be desirable.

F-506433

FIGURE 17. — A test planting of Siouxland cottonwood 6 years old. This is a rust-resistant selection made by the South Dakota Agricultural Experiment Station. Note the uniform, narrow crown, the rapid growth rate, and good foliage density.

F-506434

FIGURE 18. — A cottonwood exhibiting desirable characteristics. Note the broad crown, excellent density, and good live branch retention.

F-316894

FIGURE 19. — Many of the trees in this 80-foot-tall cottonwood belt in Stutsman County, N. Dak., exhibit superior growth rate, but there is considerable variation in individual trees. Note differences in height, diameter, live branch retention, and straightness of stem. The high percentage of superior trees in the belt should make it a good source of seed for nurseries.

F-506435

FIGURE 20. — Two 30-year-old planted cottonwoods, probably from the same seed source. Both trees are straight, and exhibit good height growth and a high degree of live branch retention. The tree on the right has the ability to retain its foliage longer in the fall than the tree on the left. In this species, this is a desirable characteristic.

F-506436

FIGURE 21. — Three phenotypes of American elm about 25 years old. The tree to the left of center is low crowned, forked at an acute angle, and shorter than others in the same plantation. The center tree is straight, tall, and good in growth rate. Branch retention and density characteristics, however, are not exceptional. The tree at the right has acute branch angles and poor vigor.

F-506437

FIGURE 22. — A desirable form of young American elm. Note the straight central stem, good growth rate, and medium-dense crown. Live branch retention characteristics are fair.

F-500502

FIGURE 23. — American elm in a single-row windbreak exhibiting different crown development. The broad tree to the right of center is probably the most desirable phenotype for shelterbelts. All trees, however, are too young to judge their characteristics accurately. Continued observation of these trees to ascertain whether they maintain these characteristics is desirable.

F-502138
FIGURE 24. — Siberian elm in a shelterbelt in Oklahoma exhibiting a uniform superior growth rate. Trees are 25 years old and average 65 feet tall.

F-431007
FIGURE 25. — Wide variation in frost resistance and winter hardiness is exhibited in *Ulmus pumila* in a 9-year-old shelterbelt in North Dakota. The tree in the center has suffered little or no damage, while the trees to the right and left of it have been frozen back repeatedly.

Siberian Elm

Siberian elm (*Ulmus pumila* L.) is being used rather successfully in shelterbelts where a fast growing, relatively short-lived tree is adequate. Read (1958) showed a 67-percent survival in 567 shelterbelts throughout the Great Plains, and George (1936) reports that losses at Mandan, N. Dak., occurred mostly as a result of freezing temperatures in early fall. He also says, "The late retention of leaves and brittleness of wood make exposed trees subject to wind and sleet breakage." There have been several named selections of Siberian elm, such as "Chinkota," "Harbin," and "Dropmore," placed on the market that appear to be more hardy than the general run of the species (Collins 1955).

It is likely that with the vast amount of this species planted in the Plains in recent years many other better-than-average genotypes may be represented.

F-506438

FIGURE 26. — A good form of native bur oak exhibiting a better-than-average growth rate, straight stem, and relatively dense crown. This tree also flushes earlier than others of the same species on the same site. A more uniform branch habit with live branches retained lower on the trunk would be desirable. The trees in the background exhibit crooked stems and inferior growth rate.

We should seek phenotypes superior in:

Drought resistance.

Resistance to leaf defoliators.

Resistance to slime flux (*Erwinia nimipressuralis*).

Less brittle wood than the species.

Vigorous growth.

Greater longevity.

Good branch retention.

Avoidance of sharp crotches.

Because of the tendency of Siberian elm to be damaged by cold in early fall, comparatively early defoliation is a desirable trait (figs. 24, 25).

Ulmus Hybrids

With the large *Ulmus* population in native stands and shelterbelts in the area, it is quite likely that intraspecific hybrids have been formed. George (1953) reports observations on several *Ulmus* hybrids. One of these has *U. pumila* as one parent and presumably *U. rubra* as the other and is exhibiting good growth form and vigor.

Selectors should be alert to possibilities of natural hybrids within this genus.

Bur Oak

Bur oak (*Quercus macrocarpa* Michx.) is a native drought and cold resistant species that has been used to a limited extent in shelterbelts. It is slow growing and difficult to transplant because of its deep tap root (George 1953). However, the survival at Mandan (George 1953) and in the shelterbelts in Nebraska and Kansas has been very good. The species would seem to merit more extensive trials.

Bur oak has an extensive geographical range and there are recognized differences in races and traits within the species.

Phenotype selections of bur oak should have (figs. 26-28):

Straight trunks, uniform branching habit, and dense crowns.

Ability to establish when transplanted.

Superior seedling vigor.

Rapid growth rate.

Early spring flushing.

Late foliage retention.

F-506439

FIGURE 27. — Two young bur oaks with desirable characteristics. The tree at the left background has retained some foliage all winter, contributing to greater winter density, but the forked stem is not so desirable. The tree in the right foreground is straight and vigorous and has desirable branching.

F-295443

FIGURE 28. — Phenotypes of bur oak. The tree on the left has superior growth rate, good branch retention, and a desirable crown density. The forked trunk is somewhat undesirable. The tendency of the tree to maintain foliage later than the majority of the species on the same site is desirable.

Boxelder

Boxelder (*Acer negundo* L.) was used for a long time as a shelterbelt tree. Recently the trend in usage has been downward, presumably because of its tendency to kill back in severely dry years and because of injury from "boxelder blight," induced by 2,4-D damage (Phipps 1963). Boxelder should be selected for resistance to winter injury, longevity, more upright growth forms, and better-than-average branch retention.

Other Tree Species

Although this guide emphasizes only those species of trees that have exhibited a potential as windbreak components, any tree species growing under Plains conditions and exhibiting superior or unique characteristics should be considered for selection. Of particular importance are phenotypes growing vigorously in unusual sites for the species, showing obvious resistance to drought, cold, insects, or disease, or growing well out of their usual range.

Shrubs

The development of a guide for the selection of superior shrubs is intended for a later date. However, outstanding shrubs exhibiting any characteristics that enable them to be more adaptable to Northern Great Plains shelterbelts should be selected. Species of special interest are Siberian peashrub, honeysuckles, lilacs, Russianolive, Amur maple, buffalo berry, and species of the *Prunus* genus.

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AUGUST 1964

BLACK BARK AS AN INDICATOR OF BIRD PECK DEFECT IN SUGAR MAPLE

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Contents

	Page
Introduction	1
Cause of Discoloration	1
Incitants	1
Sapsuckers	1
Porcupines	4
Small Rodents	4
Seams or Cracks	5
Implications for Management in Lake States Northern Hardwoods	6
Summary	7
Literature Cited	7

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Introduction

Portions of the lower bole of occasional sugar maples (*Acer saccharum* Marsh.) in Lake States northern hardwood stands are sooty black in sharp contrast to the normal gray (fig. 1). The blackened areas may encircle the entire stem or be confined to a narrow band; they have been observed as high as 25 feet but generally extend about 15 feet above the ground. Preliminary investigations indicated that nearly all such trees had been heavily and repeatedly attacked by sapsuckers. The possibility of using the black bark as an external indicator of bird peck defect in sugar maple prompted this investigation.

Black-barked trees are usually more abundant in lowland hardwood areas adjacent to swamps, probably because of the sapsucker's preference for these areas as nesting sites. In one lowland hardwood stand sampled, 8.7 percent of 150 sugar maples on 12 fifth-acre plots had sapsucker-caused black bark; in a nearby upland hardwood stand 1.4 percent of 297 sugar maples on 12 fifth-acre plots had sapsucker-caused black bark. The prevalence of black bark in stands throughout the Lake States is not known. "Walk-through" observations of many stands by the authors, however, indicate that the condition may be absent, or nearly so, in some upland hardwood stands while in many lowland stands the condition occurs so commonly that one is scarcely ever out of sight of a black-barked tree.

Cause of Discoloration

The sooty appearance is caused by the growth of a fungus complex on the bark surface. Most of the fungi comprising the hyphal mass have dark-colored mycelium and spores which appear dull black to the unaided eye. Fungi identified to date include *Fumago* sp. (probably the imperfect stage of *Capnodium*) and *Pullularia pullulans*. In addition, several other fungi have either been observed microscopically on sections of bark or cultured but have not yet been identified. Ellis and Everhart (1892) list *Capnodium expansum* Berk. and Desm. on black maple (*Acer nigrum* Michx. f.) in Ohio.

In many respects this condition appears similar to the "sooty mold" reported on leaves of various hardwoods and conifers following attack by aphids and scale insects (Boyce 1961). Fraser (1933, 1937), working with sooty molds on various plants in Australia, found complexes of various species of Capnodiaceae, Atichiaceae, and Fungi Imperfecti responsible for the sooty appearance and reported that such fungi were always associated with and growing on the sugary excretions of aphids and scale insects.

The black-bark condition on sugar maple differs in two major respects from the "sooty mold" of hardwoods. First, black bark occurs on the bole, usually on the lower portion, and not on the leaves or twigs; secondly, it is not associated with insect attacks but apparently follows either wounding by sapsuckers, porcupines, and small rodents or frost cracking with subsequent release during early spring of large quantities of sap containing a relatively higher sugar concentration. The sap saturates the dead bark, providing a food base for the fungi.

Incitants

Examination of hundreds of black-barked sugar maples revealed several main incitants, all of which involve wounding and subsequent release of sap on the bark.

Sapsuckers

Sapsucker wounding during early spring is the most important incitant of black bark. The wound pattern, part of the tree attacked, and time of wounding on black-barked trees differ from that described in the northeast by Shigo (1963) on sugar maple, red maple, paper birch, yellow birch, and beech, and in Minnesota by Roberts (1936) on sugar maple, red maple, and poplar. In that type, the sapsuckers make a concentrated attack in a relatively small area on large branches or on the

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FIGURE 1. — Two black-barked sugar maples in a second-growth stand. Both trees have been heavily and repeatedly attacked by sapsuckers.

bole at the base of the crown. According to Roberts (1936), the usual practice is for a pair to select several trees close together and near the nesting site, tapping these repeatedly to keep sap flowing throughout the summer and early fall. Young are brought to these trees to feed later in the season. Roberts states, "The birds are in the habit of returning year after year to the same places." Localized death of the cambium often results or, in some cases, death of a portion of the crown when the limb is completely girdled. Damage of this type has also been observed in stands where black-barked trees were found and is a minor causal agent in the dieback complex of northern hardwoods.

Sapsucker attacks on black-barked sugar maple are not as concentrated (many trees observed last spring had only a single horizontal line of fresh pecks) and are generally confined to the lower portions of the bole. They are apparently made only in early spring since no freshly made wounds have been observed after mid-May. Evidences of older sapsucker attack are present in the blackened bark but are very difficult to detect from distances of more than a few feet (fig. 2).

It has been reported (Pearson 1936) that males precede females in migration and that during this period their diet consists mainly of sap. At this time the birds may actually become drunk through drinking fermented sap (Sutton 1928, Pearson 1936). Because of the differences in timing, pattern, and portion of the tree attacked between black-barked sugar maple and the birds' usual "orchard trees," it seems possible that only male sapsuckers are responsible for the attacks on black-barked sugar maples and that after nesting begins the black-barked trees are abandoned for the usual "orchard trees."

Field observations on April 23, 1963, revealed many fresh sapsucker wounds on black-barked trees.[1] Sap was flowing heavily from these wounds, saturating the bark for several feet below. All black-barked trees examined at this time also had heavy concentrations of older, nonflowing sapsucker wounds on the lower part of the bole.

Several nearby sugar maples with normal gray bark were examined near each black-barked tree. One gray-barked tree had a single fresh sapsucker wound and sap was flowing from it. A few showed evidence of scattered older sapsucker wounds, but their concentration did not approach the density on black-barked trees. Most gray-barked trees showed no evidence of sapsucker attack.

[1] *Wood (1943) reported an average arrival date in the last week of April for yellow-bellied sapsuckers in the Upper Peninsula of Michigan, but they have been observed as early as April 15.*

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FIGURE 2. — Older sapsucker wounds on a black-barked sugar maple. A row of pecks extends across the stem from the pencil point. Such wounds are difficult to see at distances of more than a few feet.

Twenty black-barked sugar maples showing evidence of bird peck were felled, dissected, and examined for evidence of earlier attack by sapsuckers. These trees ranged from 3.6 to 21.7 inches d.b.h., averaging 13.9 inches. Most were in the 100- to 150-year class. All showed evidence of heavy and repeated attack, the oldest peck noted being made 128 years previously in a 200-year-old tree as determined by ring counts. The cross-section shown in figure 3 is typical of patterns found in the larger trees examined. In all trees, the first 16-foot log had a heavy concentration of pecks and their associated stain, and in several of the larger trees so did the second 16-foot log.

One possible explanation for the striking preference of the sapsuckers for the black-barked trees is that sap from these individuals might have a higher sugar content. Variations in the sugar content of maple sap between individual trees have been reported by Taylor (1956). To test this hypothesis, 10 pairs, consisting of one black-barked and one nearby gray-barked sugar maple of approximately the same size and condition, located in three different stands, were selected and tapped with a single hole on May 2. Approximately 1 liter of sap was collected from each tree, returned to the labortary, and frozen at -16° C. until analyzed for sugar content with a hand refractometer (Lafayette model F-358). Differences in percentages of sugar were not significant, the sap from black-barked trees averaging 2.1 percent sugar and that from normal trees 2.0 percent. Thus, the hypothesis that higher sugar content is responsible for the birds' preference is not supported by this experiment. Since the sap was collected rather late in the season, it is possible that significant differences may occur earlier. Other contributing factors may be differences in time of beginning sap flow, volumes released, and duration of flow.

Porcupines

One tree was found which had been badly damaged by porcupines working in the lower crown for more than 1 year. The main stem below the crown was completely black. Only two sapsucker pecks were found on this tree.

Small Rodents

Many small-diameter (less than 3 inches d.b.h.) sprouts arising near the ground line of mature gray-barked sugar maples were completely blackened (fig. 4). Numerous small wounds on the stems and branches, apparently made by small rodents, perhaps red squirrels, were observed (figs. 4 and 5). Early spring observations revealed many fresh

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FIGURE 3. — Bird peck defect as seen in cross section of a 19-inch d.b.h., black-barked sugar maple. Each dark stain is associated with a sapsucker wound. In this section the oldest wound was made 53 years previously. Total age at the section — 125 years.

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FIGURE 4. — Black-barked sugar maple basal sprout arising from a normal tree. Repeated chewing by small rodents, probably red squirrels, is the incitant on black-barked sprouts.

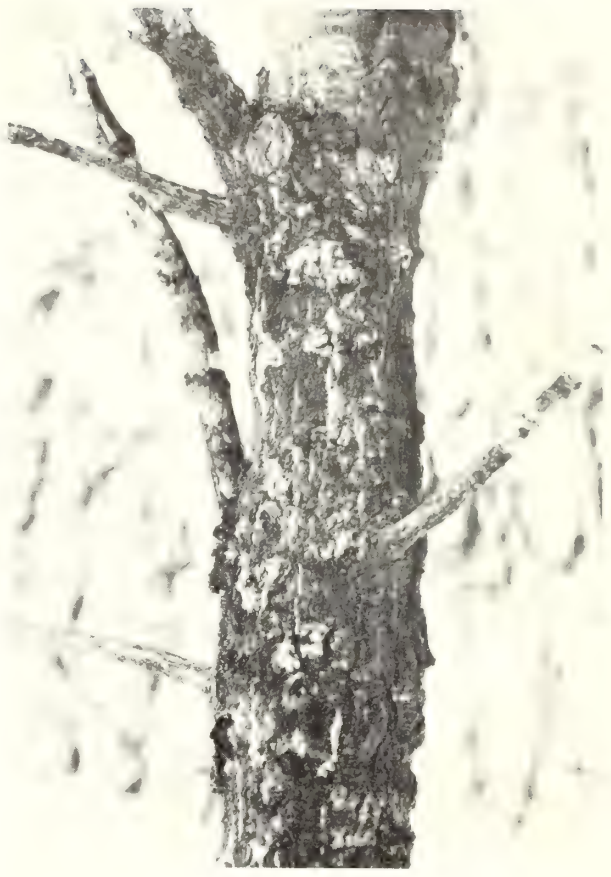

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FIGURE 5. — Close-up of a portion of the sprout shown in figure 4. Gnarled appearance is due to callusing of older small rodent wounds. Younger wounds are also visible.

wounds from which the sap was flowing freely. No sapsucker wounds were observed on the sprouts.

All small rodent attacks were confined to basal sprouts; nearby seedlings and saplings were not attacked. The reasons for this preference by rodents are not known, but the fact that sprouts are connected with much larger root systems and crowns than those of seedlings and saplings may indicate differences in sugar content or volumes of sap available. So far as is known there is no connection between these black-barked sprouts and black-barked trees attacked by sapsuckers. None of the latter showed evidence of having originated as sprouts.

Seams or Cracks

Several sugar maples of sawtimber size were located which had rather limited blackening around seams or cracks. No sapsucker pecks were found on these trees. Other seams examined did not have black bark. It is possible that only those seams which develop new breaks in the cambium due to winter freezing release sufficient amounts of sap during the following spring to support the growth of black bark fungi (fig. 6).

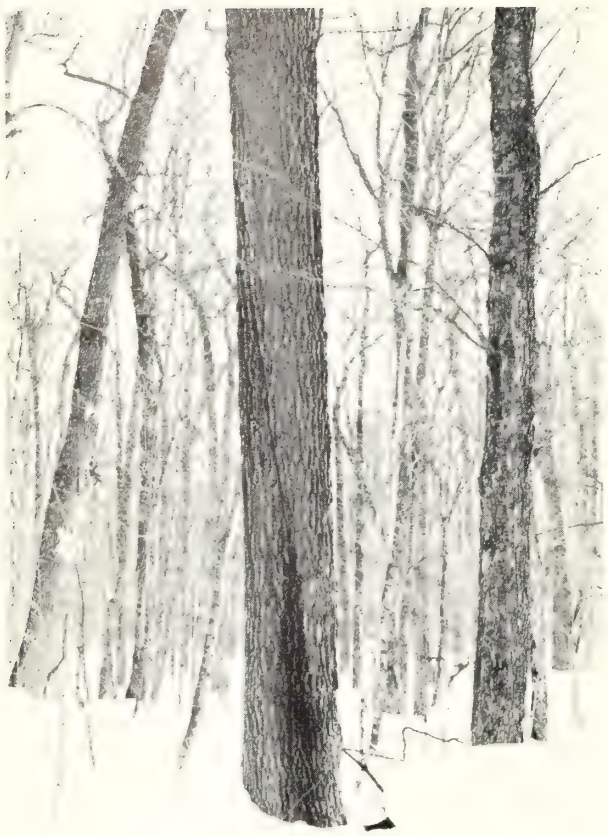

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FIGURE 6. — Black bark below a spiral seam on a mature sugar maple. Repeated opening by freezing probably causes sap flow each spring.

Implications for Management in Lake States Northern Hardwoods

Bird peck is a log grade defect in factory logs. Lockard et al. (1963) and the Forest Products Laboratory (U.S. Forest Serv. 1959) have reported on its effect on logs and lumber.

The selection system of silviculture recommended for the northern hardwood type in the region (Arbogast 1957) has as its ultimate objective the maximum production of high-quality timber. High quality is developed through removal of low-quality trees of all size classes as well as overmature and mature trees at 8- to 15-year intervals. Sugar maples which have been heavily and repeatedly attacked by sapsuckers should be removed as soon as possible if they are not necessary in the stand because of considerations of spacing, stocking, etc. Such trees must be considered poor growing stock, and the growing space they occupy should be utilized by higher quality trees.

As mentioned previously, bird pecks are difficult to see, especially at the distances from which marking crews appraise individual trees. Such trees are probably often overlooked during marking. The black-bark indicator can serve as a warning that a closer inspection for bird peck is required. An appraisal of sapsucker damage can be made by grading the butt log, using hardwood log grades developed by the Forest Products Laboratory (U.S. Forest Serv., 1959). Because of the exceptions noted previously (porcupines, small rodents, etc.) it should not be used as an absolute indicator of bird peck but only as a warning sign of its possible presence. Other causes of black bark such as seams or rodent attack are more obvious and are probably not overlooked by marking crews.

Summary

Blackening on the lower bole of sugar maples is due to a fungus complex which includes *Fumago* sp., *Pullularia pullulans,* plus several as yet unidentified fungi growing together on the bark surface. They have dark mycelium and spores which, in mass, appear sooty-black to the unaided eye. Growth of the fungus complex has been observed following attacks by sapsuckers, porcupines, and small rodents. Limited areas of bark below some frost cracks also support the fungi. All of the incitants observed cause release of considerable sap having a relatively high sugar content which saturates the dead bark and provides a food base for the fungi.

Sapsucker attacks were responsible for nearly all black-barked sugar maples examined, the other incitants being relatively minor. The wound pattern, part of the tree attacked, and time of wounding by sapsuckers differ considerably from the usual sapsucker attacks on hardwood trees. Sapsucker attacks on the lower bole of sugar maples were concentrated almost exclusively on these black-barked individuals in the stands examined, and all such trees dissected showed evidence of heavy and repeated attack.

Bird peck is a log grade defect in factory logs and such trees should be removed from northern hardwood stands managed for high-quality timber in order to concentrate growth on higher quality trees. The black-bark indicator can serve as a warning of possible bird peck defect in sugar maples, indicating that close inspection for bird peck is required.

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The Recreational Capacity of the Quetico-Superior Area

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FOREWORD

Early in 1964 the Lake States Forest Experiment Station published a report on "Recreational Use of the Quetico-Superior Area" by Dr. Robert C. Lucas. It showed the amounts and distribution of different kinds of uses, discussed the factors related to distribution, and outlined trends in use.

In the report presented here, Dr. Lucas attempts to relate the use patterns and trends to the area's capacity for producing wilderness experience for visitors. The work is an interpretation of user viewpoints and activities in terms of land management implications. Such interpretations need to be considered, along with biological, economic, legal, and other factors, in setting management policies.

CONTENTS

	Page
INTRODUCTION	1
The Problem	1
Preview of Study and Results	1
THE STUDY AREA	2
RECREATIONAL USE	5
FACTORS LIMITING CAPACITY	5
Physical Factors	5
User Attitudes	7
Attractions of the Area	7
The Area Considered Wilderness	9
Effect of Recreational Use on Wilderness Perception	9
Location in Relation to Wilderness Perception	19
Development in Relation to Wilderness Perception	19
Nonrecreational Use in Relation to Wilderness Perception	21
THE CAPACITY OF THE QUETICO-SUPERIOR AREA	22
Assumptions Made in Defining Capacity	22
The Distribution of Underuse and Overuse	23
THE RELATION OF TRENDS TO CAPACITY	25
SUMMARY	26
MANAGEMENT IMPLICATIONS	27
A Framework for Recreational Policy	27
Major Present Policy Problems	27
A Suggested Approach to Use Separation and Dispersal	28
Separation	28
The Feasibility of Concentric Zoning	30
Dispersal	31
Other Policy Considerations	32
Limiting Amounts of Use	32
Logging	32
Roads	32
Campground Facilities	33
Canoe Campsites	33
Portages	33
A FINAL COMMENT	33
LITERATURE CITED	34

INTRODUCTION

The Problem

An important and probably essential characteristic of a wilderness is limited use. Crowds are absent, and man's mark on the landscape is minor. But more and more people go to the wilderness each year, and the press of numbers threatens to wipe out the wilderness qualities. This was recognized by Aldo Leopold, one of the major contributors to the stream of ideas which has led to the establishment of 84 National Forest wilderness-type areas covering over 14 million acres. He wrote (1949, p. 101): "Thus always does history, whether of marsh or marketplace, end in paradox. The ultimate value of these marshes is wildness. . . . But all conservation of wildness is self-defeating, for to cherish we must see and fondle, and when enough have seen and fondled, there is no wildness left to cherish."

If conservation of wildness is not to be self-defeating, there must be a compromise between complete wilderness with no visitors and, at the other extreme, crowds and no wilderness. Neither extreme provides any wilderness experience; some middle ground is unavoidable if the well-established social goal of providing an opportunity to experience wilderness is to be maintained. But where is the middle ground?[1]

The problem of climbing recreational use and retreating wilderness is general (fig. 1). At present, however, probably only a few more frequently visited wilderness regions are near the critical zone on the compromise spectrum. The Quetico-Superior Area is one of these heavily used wilderness regions (Lucas, 1964a). The portion of the Quetico-Superior Area in the United States, the Boundary Waters Canoe Area of the Superior National Forest, is the most used Forest Service wilderness-type area in terms of visits and man-days, and one of the most used on a man-days-per-acre basis, according to official use estimates. Use of the Canadian portion, Ontario's Quetico Provincial Park, is less, but still substantial, and some parts are heavily used (Lucas, 1964a).

The wilderness areas under the heaviest pressure are good subjects for wilderness capacity research. Here the limits to wilderness use should be most apparent, and findings should have application to future conditions for wilderness now lightly travelled but with an expected rapid increase in use. Official estimates of wilderness visits to the National Forests show a higher rate of increase than do figures for conventional recreational visits, and projections suggest that this gap will widen substantially. A tenfold increase in wilderness man-days of use has been projected for 2000, and an eightfold growth for the Boundary Waters Canoe Area (Wildland Research Center, 1962, p. 236). In contrast, only a threefold increase has been projected for all outdoor recreation by the same date, and a fourfold expansion for general camping (Outdoor Recreation Resources Rev. Comn., 1962, p. 46).

Preview of Study and Results

There are three parts to the study reported here. First, the factors limiting capacity are considered. The physical factors are discussed only

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FIGURE 1. — As more people seek the wilderness, will it become harder to find? This large fleet of canoes, only part of which can be seen in the photograph, suggests how heavy use has become in a few places.

[1] *For similar ideas and a call for research to identify the critical levels of wilderness resource use, see Fisher, 1960.*

Note: The author is a geographer, Lake States Forest Experiment Station. The Station is maintained at St. Paul, Minn., by the Forest Service, U.S. Department of Agriculture, in cooperation with the University of Minnesota. The author gratefully acknowledges the guidance and stimulation of Dr. John R. Borchert, University of Minnesota, and Dr. Gilbert F. White, University of Chicago.

briefly. Undesirable ecological changes — wear and tear of soil and vegetation — were not studied except for some limited information on how visitors rated physical wear.[2] The main emphasis is on visitors' perception of the recreational resources of the Quetico-Superior. Data are presented on the importance of the wilderness and other qualities to various user groups, the area considered wilderness, and the characteristics of the wilderness.

Different types of visitors varied in their views of all three of these points. Canoeists were attracted to the area mainly by its wilderness qualities; other types of recreationists saw fishing or scenery as primary. The canoeists saw the wilderness as much smaller than all other visitors. Canoeists considered the wilderness overcrowded at much lower levels of use than others and objected strongly to motor boats. Logging was seldom noticed by any class of visitors, and many did not object to it when they did discover it.

Second, a method for estimating the wilderness capacity of the Quetico-Superior is suggested. This is based directly on the data dealing with the characteristics of the wilderness — especially what people think about the amount and kind of use they encounter — and only indirectly on physical environmental change. Using this method, the capacity of the Quetico-Superior for high-quality wilderness recreation is estimated. Total use seems to be fairly close to capacity, but removing motorboats from the interior would increase capacity substantially. Then, areas of over- and underuse are mapped, drawing on use distributions in the previous paper, "The Recreational Use of the Quetico-Superior Area" (Lucas, 1964a). Underused areas are larger than those overused. Use trends are reviewed, and it is concluded that capacity may be reached or exceeded soon.

Third, management implications of the findings are discussed. The focus is on possible means of better achieving the official goal of a wilderness canoe country. Separating incompatible boating and canoeing seems most important, and zoning seems to be the most useful and feasible approach to separation. Dispersing canoeists is also probably desirable, and a better flow of information may help spread out users. Eventually, however, a choice must be made between limiting numbers of visitors or losing the wilderness environment, at least as it is now defined by visitors.

THE STUDY AREA

The Quetico-Superior Area straddles the border between the United States and Canada (fig. 2). The emphasis in this study, however, is on the part in Minnesota, the Boundary Waters Canoe Area of the Superior National Forest. Capacity is a more immediate problem there than in Quetico, because use is heavier and use conflicts are greater.

The setting, both the internal conditions and the location relative to population and to other recreational areas, was discussed in some detail in the previous paper (Lucas, 1964a) and will not be repeated here.

The management goals and policies may be briefly restated. On both sides of the border the main objective is to provide a wilderness lakeland setting for recreation, without completely eliminating timber harvesting. For the Superior, the recreation is further specified to be wilderness canoeing. The regulations designed to achieve these goals are as follows (for a short history of these regulations, see Lucas, 1964b; Wildland Res. Center, 1962):

1. Roads are prohibited, except temporary timber harvest roads closed to public travel.

2. Air travel below 4,000 feet above sea level is illegal, except for flights to peripheral points of entry to Quetico Park, and administrative flights (particularly fire patrol) in both countries.

3. Motor boats are "prohibited except where the employment of such facilities by the public has been well established" in the Boundary Waters Canoe Area. There has been no announcement as to areas closed to boats, however. Quetico Park has no motorboating regulations.

[2] *A later cooperative study with the School of Forestry, University of Minnesota, is concentrating on the question of physical change induced by use of canoe campsites.*

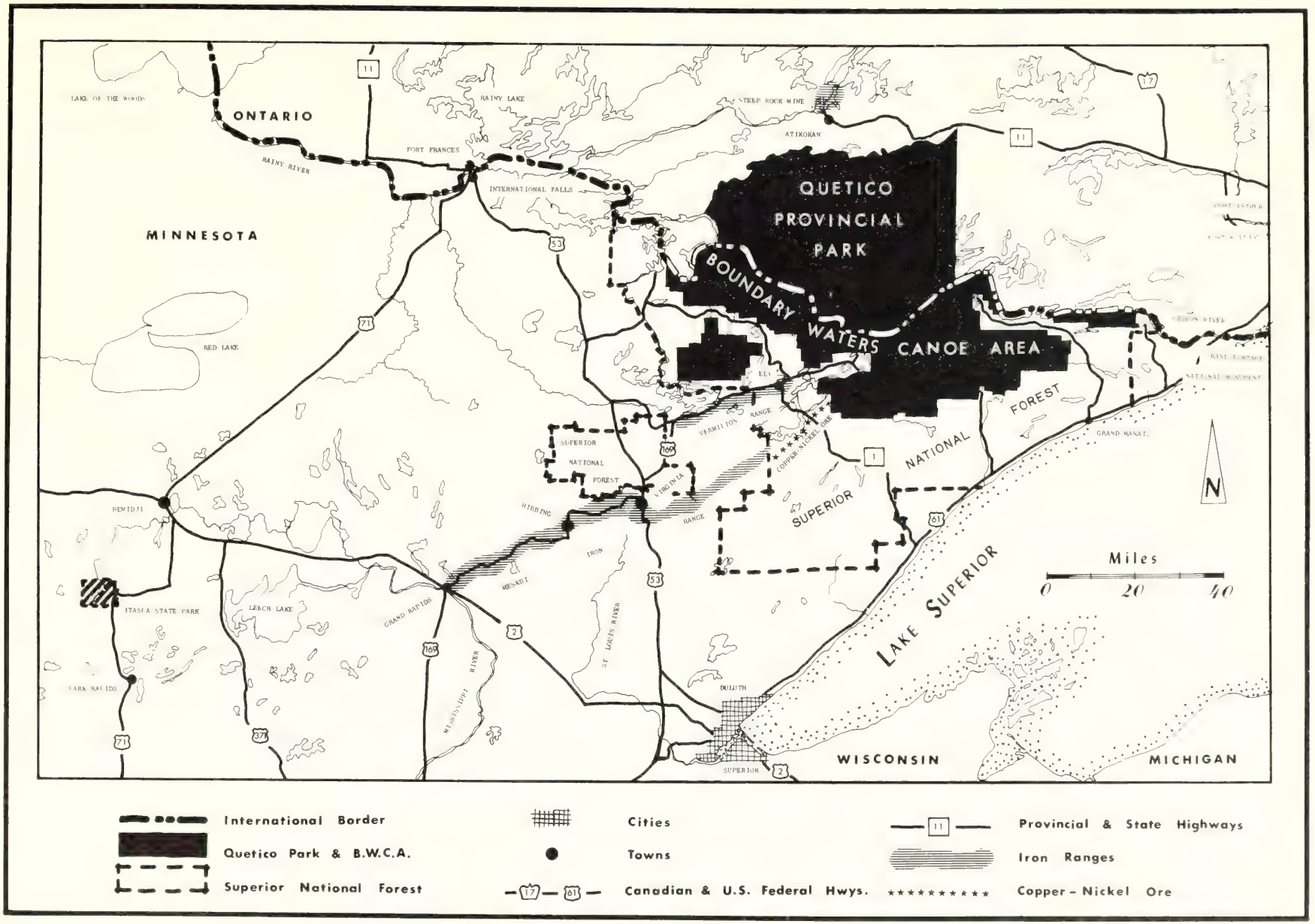

FIGURE 2. — The regional setting.

4. Storing boats or canoes on public land between periods of use is not allowed in Quetico Park. Leaving unattended equipment on National Forest land is generally prohibited, and enforcement on the Superior is planned in 1965.

5. No resorts or summer homes can be built on government land. This restriction also applies to a one-mile-wide buffer zone around Quetico Park.

6. Logging of shoreline stands or near portages is not permitted. One-third of the Boundary Waters Canoe Area is entirely closed to logging. (See Lucas, 1963, for a fuller description of this policy.)

7. Mining is generally excluded except for possible national emergencies, although because of outstanding mineral rights on some property the control is not complete in either country.

8. Dam construction is prohibited in almost all of the Boundary Waters Canoe Area. There appears to be no written policy in Quetico, although the International Joint Commission, half of whose members are Canadian citizens, ruled unanimously against dams on the Quetico-Superior border waters in 1934.

9. Quetico Park is a game preserve (except for a few Indian trap lines). Most of the Boundary Waters is open to hunters and trappers.

10. There are no special regulations on fishing.

11. Developments, such as canoe campsites and portages are simple. Most campsites have been developed by campers, some originally by Indians or Voyageurs. A few sites in Minnesota have had simple latrines, garbage pits, fire grates, and occasionally tables added by the Forest Service.

12. Private land in the Boundary Waters Canoe Area is being purchased or acquired through exchange by the Federal Government. To help recreate wilderness conditions, the Forest Service removes buildings and other improvements. This acquisition program is nearing completion. There is no private land in Quetico Park.

These policies have evolved, usually out of controversy, over a 40-year period. Both halves of the Quetico-Superior were established by governmental action in 1909 from remote lands, generally not claimed for other uses. The early plans for conventional road development in Minnesota were debated and rejected in the late 1920's. Proposed water impoundments were rejected in the early 1930's. Shoreline timber was reserved on the Superior in 1930, and in Quetico in the 1940's. The large land acquisition program in the Boundary Waters Canoe Area began in 1948 and was expanded later. Policy statements limiting use of motorboats in the Boundary Waters Canoe Area also date back to 1948. Private air travel was terminated in the early 1950's. Storage of boats and canoes will end in the 1960's.

The Quetico-Superior, generally thought of as a wilderness, is really a semi-wilderness. It is the only established National Forest area where timber harvesting and wilderness recreation are combined.[3]. Algonquin and Superior Provincial Parks in Ontario have similar policies. The rarity of this type of refuge from mechanized, commercial recreation is somewhat surprising. There have been many appeals for such recreational areas as a necessary element in the range from strict wilderness to mass recreation developments (Outdoor Recreation Resources Rev. Comn., 1962, p. 71; Wildland Res. Center, 1962, p. 11, 303; Carhart, 1961.) The founder of the Wilderness Society, Robert Marshall (1933, pp. 473-476), called for semi-wilderness in addition to primeval areas. Perhaps compromises lack the emotional appeal of more extreme positions. As a potential model for similar future areas, the Quetico-Superior seems even more important for study. Establishing more semi-wilderness areas may be one way of meeting the expected rise in visits to wilderness-type areas.

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[3] *High mountain areas in the National Forests of the Pacific Northwest are managed in a way which has some aspects of semi-wilderness. Recreation is the first priority use and other uses are carefully controlled. However, some of the land will be developed for conventional auto recreation and only part for primitive, back country recreation. (See U.S. Forest Serv., Region 6, 1962.)*

RECREATIONAL USE

The recreational use of the area was described in a previous study (Lucas, 1964a); but a brief review here will provide the reader with the background needed to better understand the capacity problem.

An estimated 132,000 people visited the study area from June 11 through September 9, 1961; 76,000 visited the Boundary Waters Canoe Area and/or Quetico Provincial Park. Canoeists outnumbered any other single type of users, and are increasing faster than other user types.

Every type of use was very unevenly distributed geographically. A few places were crowded; more were seldom visited.

Paddling canoeists covered almost all of the area, but over half entered at Moose Lake (see fig. 3 for locations mentioned in the text). The popularity of Moose Lake seemed related mainly to its good access to Quetico Park. Use at other access points also was greater at places close to Quetico Park and to Canada, at large lakes, and at places with outfitters. A portage between parking area and the water, increasing miles of gravel road, and greater distance from Duluth did not seem to reduce use. Use declined slowly along the canoe routes; half the groups penetrated at least as far as the fifth lake.

Motor canoeists were also centered on Moose Lake, but less intensely. They visited less of the area. The same factors as for paddling canoeists were related to use, but motor canoeists tended to make fewer portages than did paddlers; half the groups penetrated to the fourth lake.

Other types of visitors concentrated on the large lakes reached by roads or mechanized portages, and left most of the area unused. Auto campground use was not strongly related to site qualities; only availability of drinking water or location on large lakes seemed to be associated with heavier use. Visits by all types primarily using boats, other than auto campers, were positively related to large lakes, major water routes, access to Canada and Quetico, and, for boat campers, to direct access by car and boat trailer to the water. Boat use away from access lakes declined much more rapidly than canoe use; only one-fifth of the boating parties portaged to the second lake except where mechanical aids were available. Reasons for the choice of routes by boaters seemed vague or even random.

FACTORS LIMITING CAPACITY

The capacity of a recreational area is its ability to provide satisfaction — this is the service being produced, and this service must be described both in quantity and quality terms. Two types of factors set limits to numbers of people and their satisfaction: (1) Physical factors, and (2) the attitudes of people. Both types of factors are related to the resource base and to its use and management.

Physical Factors

Some physical elements limit numbers of people, although satisfaction may decline before the full physical capacity is reached.

Fringe access points and campgrounds in the study area (outside the Boundary Waters Canoe Area) had limited capacity, but visitors and the Forest Service tolerated overcrowding on peak holiday weekends — for example, the Lake Jeanette Campground was filled to well over three times its capacity on July 4, 1960. Normal capacity of all access parking areas in 1961 was estimated at about 1,000 cars. There were 154 campsites in 14 campgrounds within the Minnesota portion of the study area, plus the adjacent South Kawishiwi River Campground (fig. 3). This would enable over 600 people to camp on developed family units at one time, if groups averaged 4 members. There was also camping between sites at peak times. Only 17 percent of the auto-camper sample complained of crowding in campgrounds, however.

Resorts and cabins had the most definitely limited capacity of all. Fifty-nine resorts at access points had an estimated capacity of about 2,000 people at one time — over three times the campground capacity. Private cabins around the fringe

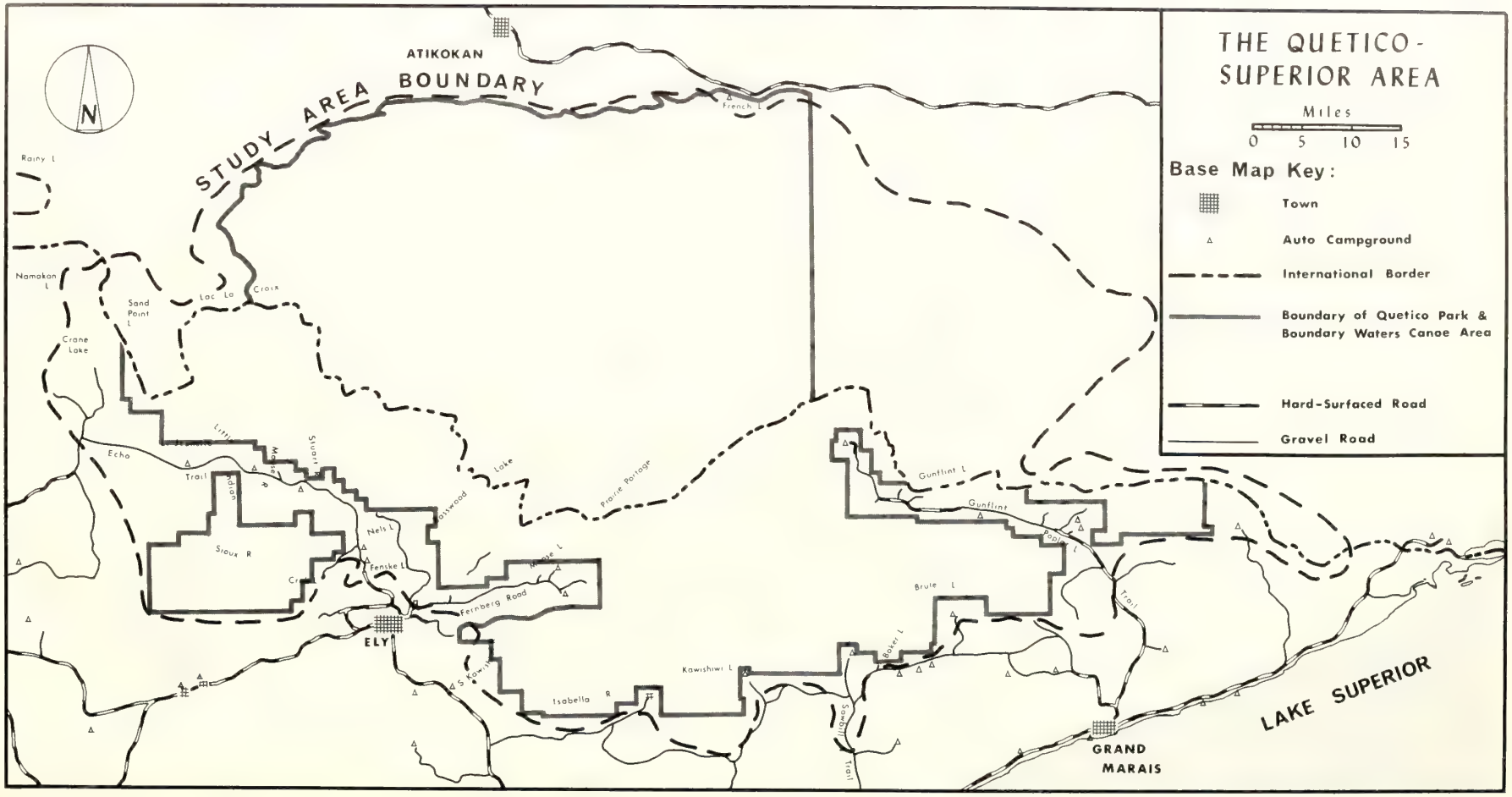

FIGURE 3. — The study area and places mentioned in the text.

totaled some 340 or roughly 1,400 persons, assuming groups of four.

The only auto access point to Quetico Park in 1961 was French Lake, in the northeastern corner of the Park. It had a large parking lot and campground (110 campsites), and resorts were nearby.

Capacity inside the canoe country is limited by similar physical factors. Canoe route campsites (also used by motorboat campers on the more accessible fringes) were difficult to enumerate. About 300 were maintained in the Boundary Waters Canoe Area by the Forest Service in 1961. In addition, a thousand or more campsites have been cleared by canoeists. Together, these sites may have as much as 10 times the campground capacity. Camping away from a previously used site was difficult in the rocky, swampy, brushy country; and potential sites, needing only some brush removal, were not very abundant, so that this was a rather effective physical limit. However, the number seemed fairly adequate; 90 percent of the sample boat campers and 75 percent of the canoeists reported no difficulty finding unoccupied sites.[4]

Two additional physical aspects of these isolated campsites set upper limits. Firewood was one. Especially on small island sites (which seemed to be almost everyone's first choice) wood supply was limited, and overcutting could spoil the appearance of such spots quickly. Sanitation was the second problem. Garbage and human wastes accumulate, and removal from such widely spread, poorly accessible places is expensive and difficult. In addition, vegetation loss due to recreational use is often large due to the generally shallow soils and the fragility of much of the ground cover, especially the mosses and lichens. Vegetation changes set a less definite physical limit, but probably reduce the visitors' satisfaction.

Within the Boundary Waters Canoe Area, 13 resorts could accommodate between 300 and 400 people in 1961, less than one-fifth the capacity of the fringe resorts. The 57 private cabins inside the Boundary Waters Canoe Area in 1961 could accommodate about 250 people, again small compared to the capacity of the peripheral cabins. Some of these have been removed since 1961, and all of the remainder will soon be gone.

These physical limits are real, although most are not yet seriously pressing. If it were considered desirable and necessary to raise any of these physical ceilings, however, it usually would be comparatively easy if the money were available. For example, in three seasons the capacity of National Forest campgrounds was doubled over the total that had been developed during the preceding 30 years.

User Attitudes

Important limitations on capacity are set by visitors' attitudes towards the area and its management and use. These limitations are difficult to overcome, partly because different groups hold incompatible views and partly because we know little about how these attitudes form or how they can be changed.

Attractions of the Area

Basic to capacity limits based on attitudes is knowledge of what qualities of the Quetico-Superior area attracted people in the first place. A visit to the Canoe Country was the primary purpose of almost all trips; very few people stopped as part of a longer trip, as would be common at Grand Canyon, for example (table 1). Many of these people had very vague ideas as to just where the Boundary Waters Canoe Area was, and some

TABLE 1. — *Number and percent of parties stating that a visit to the Boundary Waters Canoe Area was the primary purpose of their trip*

Type of recreationist	Number of sample groups	B.W.C.A. visit the primary purpose	
		Number	Percent
Canoeists	85	84	99
Day-users	9	9	100
Auto campers	96	86	90
Boat campers	24	23	96
Resort guests	57	57	100
Private cabin users	21	21	100
Total	292	280	96

[4] *A sample of each visitor type was chosen randomly over the entire study area during the summers of 1960 and 1961. In total, 292 groups were interviewed. Details of the sample selection and copies of the questionnaire forms are available in mimeographed form upon request to the Station.*

thought they had been in it when they had not. Many people probably interpreted the name as a general descriptive phrase, similar to "border lakes," instead of an official title for a specific area.

The people who considered a visit to the Canoe Country as their primary purpose were then asked what characteristics of the area, if any, caused them to choose it rather than some other vacation region in the United States or Canada. Some people, who apparently did not consider the area to be different (col. 3, table 2), replied that, "I live near here," "I have friends or relatives here," or gave the tautological answer, "I like it." These responses were most rare among canoeists and people in the auto campgrounds. They were most common among private cabin visitors, for whom the location of the cabin, once built, eliminated any further choice of area. Such answers were also common for people using the area only for the day, mostly local folk.

Answers classified as wilderness qualities (col. 4, table 2) included: "wild, uncivilized, primitive, uncommercialized, remote, uncrowded, quiet, peaceful, no outboard motors." It is recognized that these terms may have held different meanings for different groups, and also that some people interviewed may have thought of fishing or scenery as wilderness qualities. The table does suggest the relative importance of wilderness as an attraction, however. It was of major importance for canoeists (especially paddlers) and was important for roadside campers, but it was secondary for all other visitor types. Only canoeists mentioned wilderness in more than half of the interviews.

This evaluation of wilderness attractions seems to be of the same general magnitude as that reported by Taves, Hathaway, and Bultena (1960, pp. 12-13), who asked what differences people felt set the Quetico-Superior apart (these are only differences, not necessarily attractions). Roughly comparable wilderness qualities were mentioned by 58 percent of their respondents.

The user classes did not differ significantly in the frequency with which they mentioned fishing as an attraction unless the two classes of canoeists, who were at the opposite ends of the scale, are considered separately. Motor canoeists mentioned

TABLE 2. — *Percent of parties citing certain qualities as a basis for choice of the area (summer, 1960 & 1961)*

Type of recreationist	Number of sample groups	Attractive qualities cited, percent of groups[1]				
		None, vague, tautological	Wilderness	Fishing	Scenery	Facilities
Canoeists	84	6*	71*	29	28	6
Paddlers	63	6	75	16**	29	8
Motorized	21	5	62	67**	24	0
Day-users	9	33*	33*	33	11	0
Auto campers	86	8*	49*	29	30	13
Boat campers	23	17*	35*	48	26	13
Resort guests	57	12*	39*	42	42	9
Private cabin users	21	38*	10*	14	33	0
Total	280	12	49	33	32	9

[1] *All responses, sometimes three or four per party, were tabulated and therefore totals exceed 100 percent.*

* *The six major types of recreationists (ignoring the subdivision of canoeists) differed significantly in the frequency of mention of two attributes (none, vague, etc., and wilderness) at the 0.005 level when tested by chi-square. In other words, there was only one chance in 200 of such large differences occurring just by chance in a sample of this size. The six major types did not differ significantly for other qualities.*

** *The two types of canoeists differed in the frequency of mention of fishing as an attraction at the 0.001 level.*

fishing more often than any other visitor type, and were the only ones to cite fishing over half the time. In contrast, only about one-sixth of the paddlers mentioned fishing. The motor canoeists also complained most about poor fishing on a free-response question about disappointments (26 percent, compared to 3 percent of the paddlers and 20 percent of the motorboaters). These two types of canoeists differ in many ways, despite seeming similarities which have led previous researchers to place them in one class. Apparently the paddlers see the Quetico-Superior as a place for wilderness travel and camping, and the motor canoeists see it as a place for wilderness fishing.

Scenery was fairly important for all types except day-users. Resort guests and auto campers mentioned scenery as often as fishing.

Facilities were minor as an attraction for every type of visitor.

The Area Considered Wilderness

The area that was viewed as wilderness also varied significantly from one type of recreationist to another.

Figures 4 through 7 show the wilderness as seen by four of the major classes of recreationists. These maps represent the responses to the question, "Where did the members of your group feel 'the wilderness' began?" This was combined with data indicating where the group had been, and produced a "vote" by each party as to whether a particular lake or section of road was or was not wilderness, in their terms. The aggregation of these votes formed the basis for the maps.

The opinions of motorized canoeists and private cabin groups were not mapped because the samples were small and unevenly distributed. In general, the motorized canoeists viewed as wilderness an area that was larger than for paddlers, but smaller than for the various other groups. These maps indicate the amount of variation in the perceived wilderness between people *within* the class. Figure 8 summarizes this series of maps and facilitates the comparison of wilderness perceptions *between* the classes by showing the boundaries of the areas considered wilderness by at least 50 percent of the groups in each type.

The paddling canoeists perceived the wilderness as smaller and more cut up than did other users. They considered the wilderness to be *smaller* than the administratively defined area. Only one area of their wilderness was outside the Boundary Waters Canoe Area; this was the area directly north of Ely.

There was so little use of the Little Indian Sioux portion of the Boundary Waters Canoe Area (northwest of Ely) that no samples were obtained.

In Canada the situation was reversed; a large area *outside* Quetico Park was considered wilderness, particularly in the east; however, new roads are penetrating this area. No data were collected for the northern part of Quetico Park.

Apparently all types of visitors other than canoeists saw a much larger wilderness than contained within the Boundary Waters Canoe Area. The differences between the various types were not significant. Auto campers, boat campers, and resort guests all had similar views of the wilderness, and many of the small differences resulted from different locations of sample groups. All of these groups used motorboats primarily, and this common factor, rather than the type of accommodations used, seems the critical variable.

Effect of Recreational Use on Wilderness Perception

The most important variable affecting wilderness perception seemed to be amount and kind of recreational use. Different categories of recreationists differed sharply in their attitudes towards these two aspects of use. The major differences divided along the same lines as the areal concept of wilderness. The canoeists wanted much lower levels of use and distinguished more sharply between sorts of groups met than did motorboaters. A lesser difference existed between the paddling and motor canoeists.

Visitors were first asked, "What (if anything) about the area bothered or disappointed members of your group?" The interviewer did not suggest answers. Canoe-trippers and auto campers mentioned crowding most often (table 3). Most of the complaining auto campers were canoeing, usually paddling; the type of craft used seemed to condition strongly the perception of crowding. as the second part of table 3 shows.

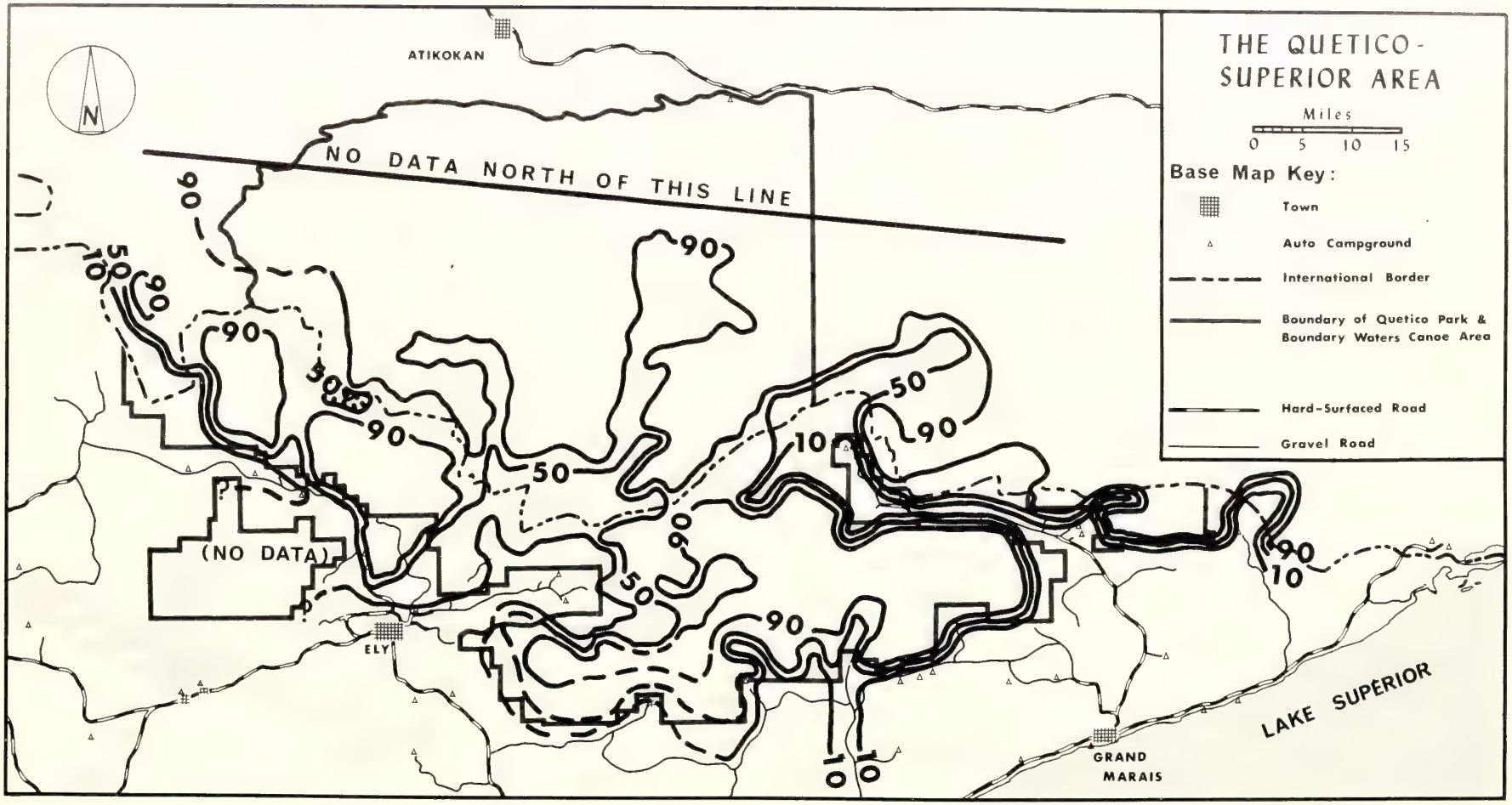

FIGURE 4. — The area considered "wilderness" by the paddling canoeists. The isoline values are the percentage of parties visiting each area which described that area as being "in the wilderness." The broken portions of the isolines indicate that data were lacking and subjective estimates were made. The map is based on 1960 data.

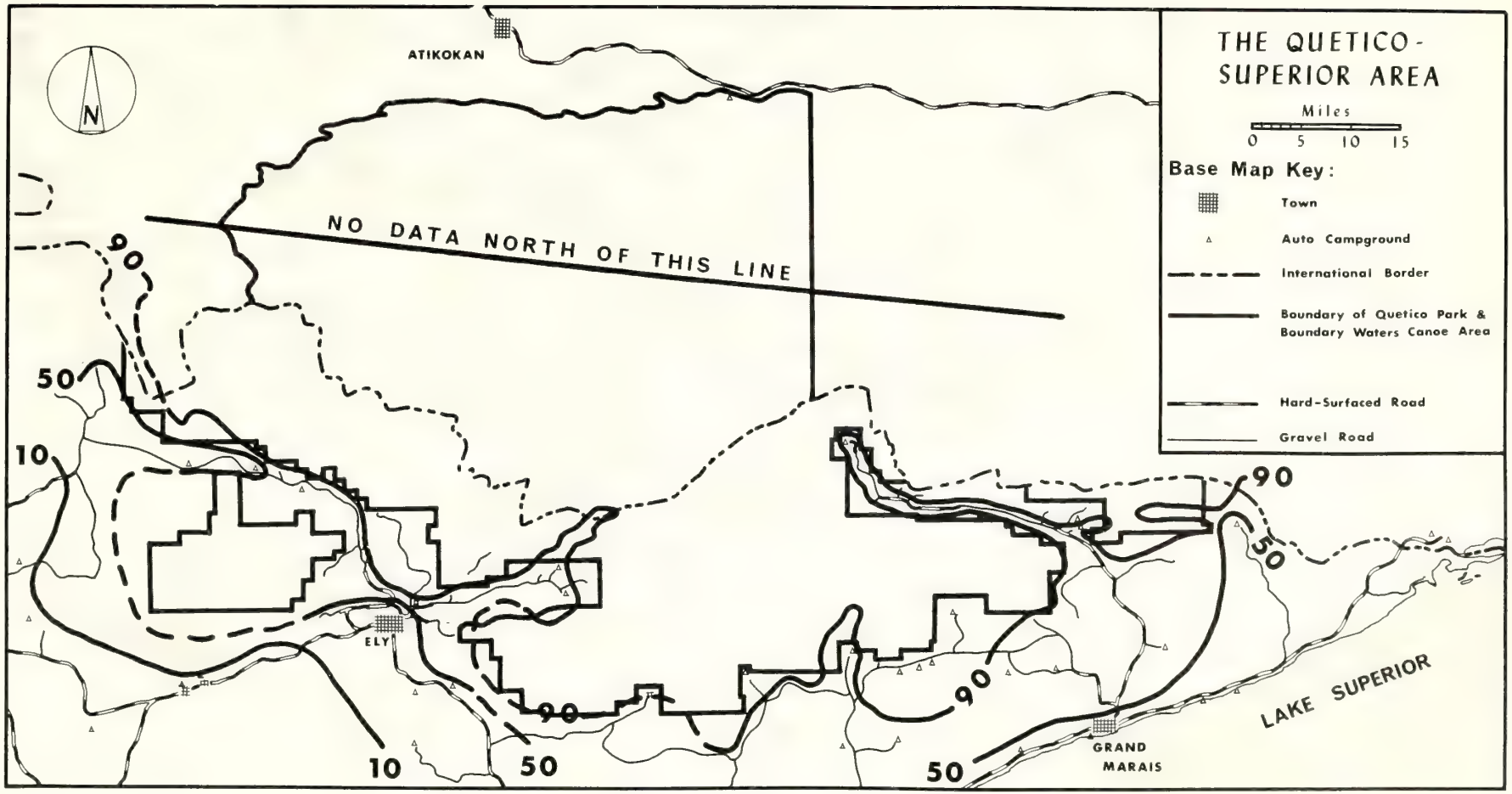

FIGURE 5. — The area considered "wilderness" by the auto campers. Definitions are the same as in figure 4.

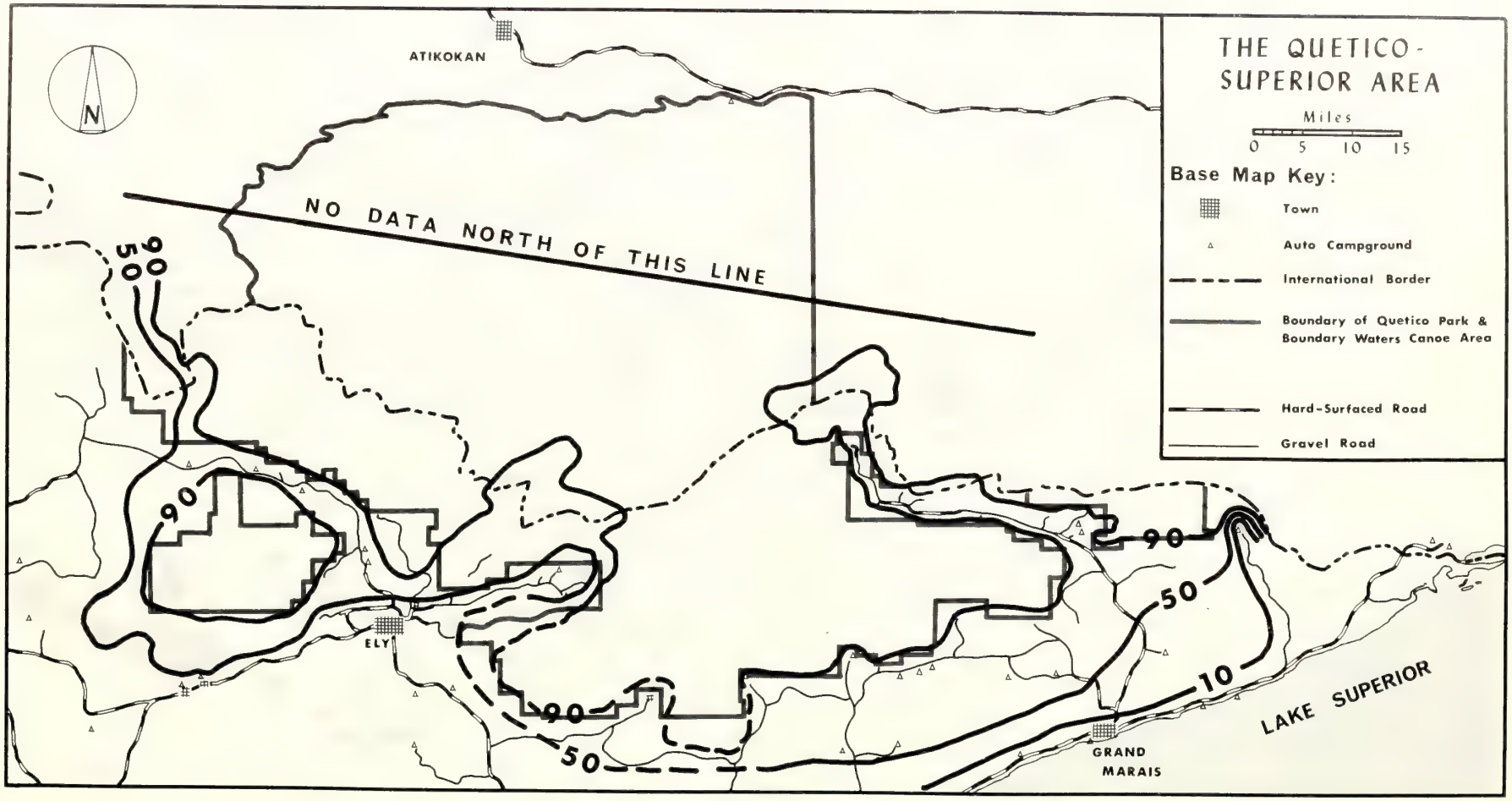

FIGURE 6. — The area considered "wilderness" by the boat campers. Definitions are the same as in figure 4. The map is based primarily on 1960 data, with some 1961 information.

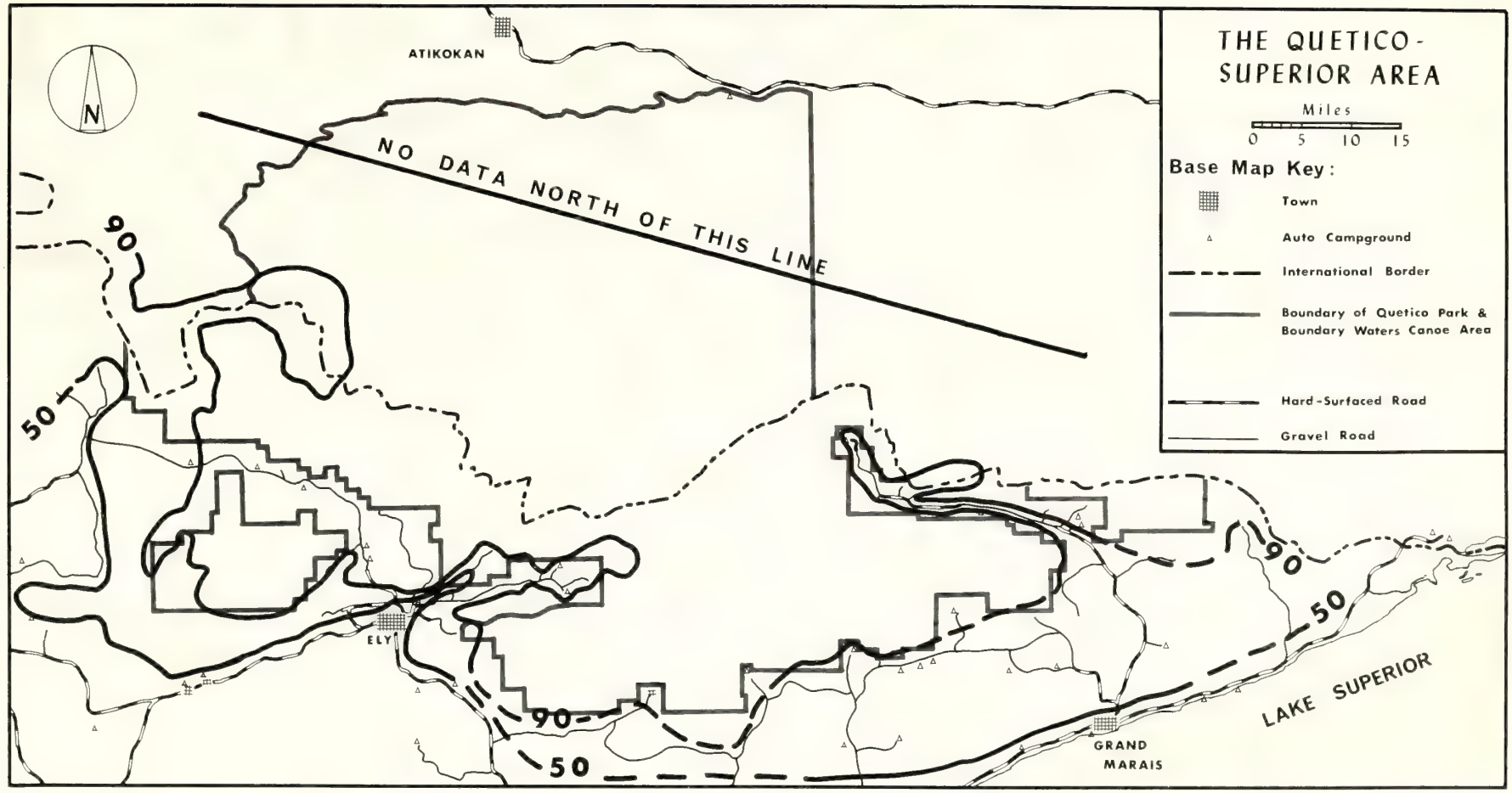

FIGURE 7. — The area considered "wilderness" by the resort guests. Definitions are the same as in figure 4. The map is based primarily on 1960 data, with some 1961 information.

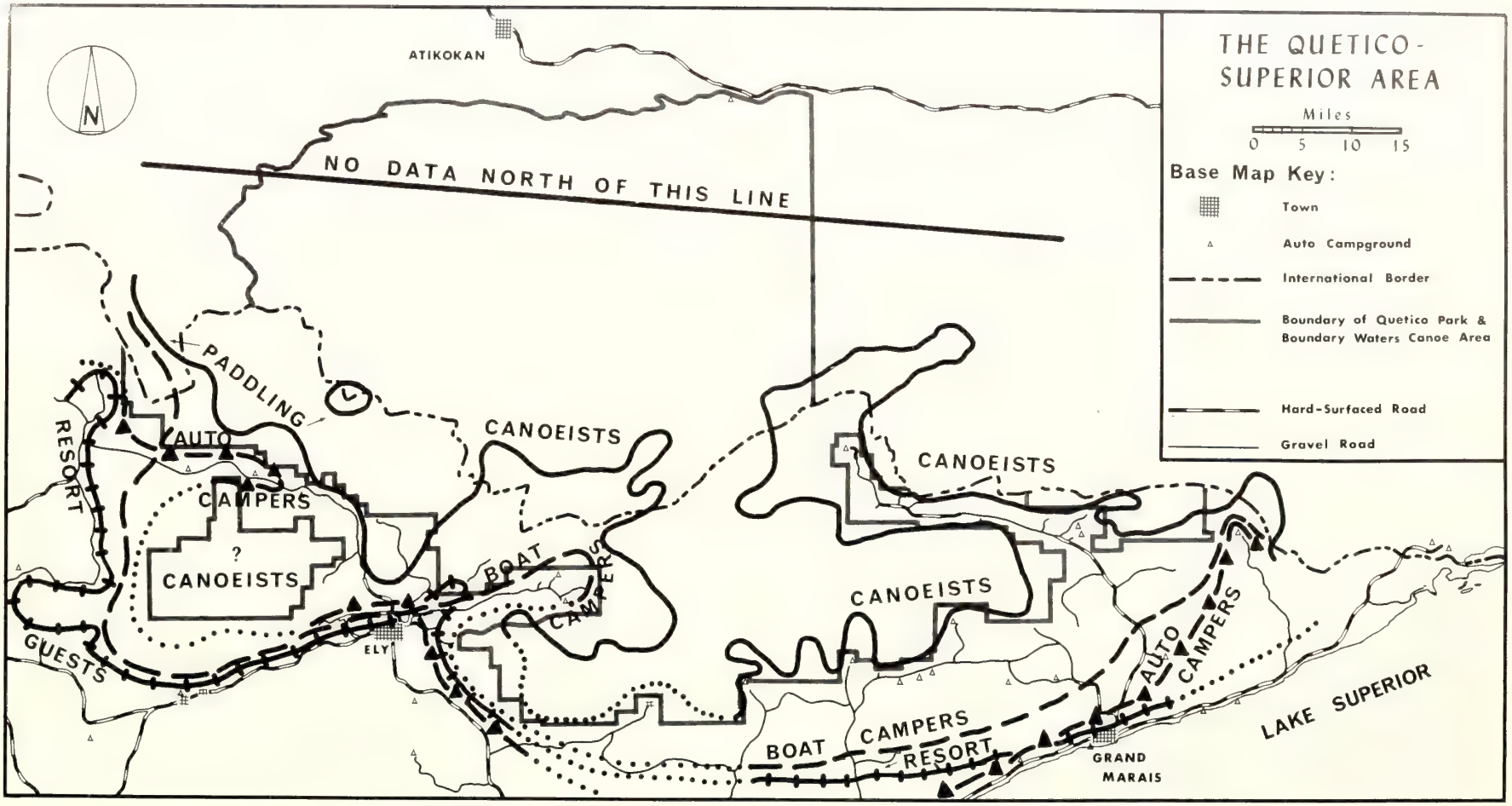

FIGURE 8. — The area considered "wilderness" by at least 50 percent of the visitors in each of the four major user types. The area in the interior, that is, away from the roads and generally to the north of the line for each user type, was rated as "wilderness" by 50 to 100 percent of the visitors of that type reaching the area. The dotted portions of the lines indicate that data were lacking and subjective estimates were made. Based on 1960 data, primarily.

TABLE 3. — *Number and percent of various categories of recreationists mentioning overcrowding as a disappointment (free-response question)*

Type of recreationist	Number of sample groups[1]	Mentioning crowding:	
		Number	Percent
Canoeists	85	9*	11
Day-users	9	0	0
Auto campers	96	10*	10
Boat campers	24	2*	8
Resort guests	57	1*	2
Private cabin users	21	0	0
Total	292	22	8
Paddled canoe	92	12**	13
Motorized canoe	38	4**	11
Motor boat	144	6**	4
No boating	27	1**	4
Total	301	23	8

[1] *A few parties used more than one type of craft, and totals in the lower half of the table therefore exceed those in the upper half.*

* *Significantly different only at the 0.25 level, tested by chi-square. The differences could occur by chance one time out of four.*

** *Significantly different at the 0.10 level, tested by chi-square. There is less than one chance in ten of the differences being the result of chance.*

Visitors were asked specifically later in the interviews, "Were members of your group bothered by crowding on any lakes in the area?" Except for canoeists, crowding was not a serious problem and differences between groups were small (table 4). But canoeists complained of crowding more than twice as often as any other group. Most dissatisfaction was expressed by paddling canoeists ending their trips at very heavily used Moose Lake; among these, 54 percent complained of overcrowding (table 5). This suggests that crowding is a local problem and that, if use increases, it may become a problem in other places.

The reaction to use intensity was approached in still another way. Groups were asked how many other groups they had met on an average day, and whether they felt these numbers were too many, about right, or too few (only one party said they met too few people). The canoeists presented a distinct pattern (fig. 9); they reacted very consistently to increasing use and in general were most sensitive to use. The erratic data for other groups suggest more heterogeneous views of crowding.[5]

Canoeists seemed to react to two critical points in use intensity. One occurred when anyone was met and complete solitude was lost. (This seemed to be the only critical point for the other user types.) The second critical point was reached when 6 to 10 groups were seen in a day; at this level a majority complained.

A smaller number of groups was informally asked, "How many canoeing and motorboating

[5] *Part of the inconsistency may be due to somewhat smaller samples for noncanoeists: A number of auto campers did not use the lakes, by mistake some resort guests and private cabin users were not questioned on this point, and a few early questionnaires did not contain the question.*

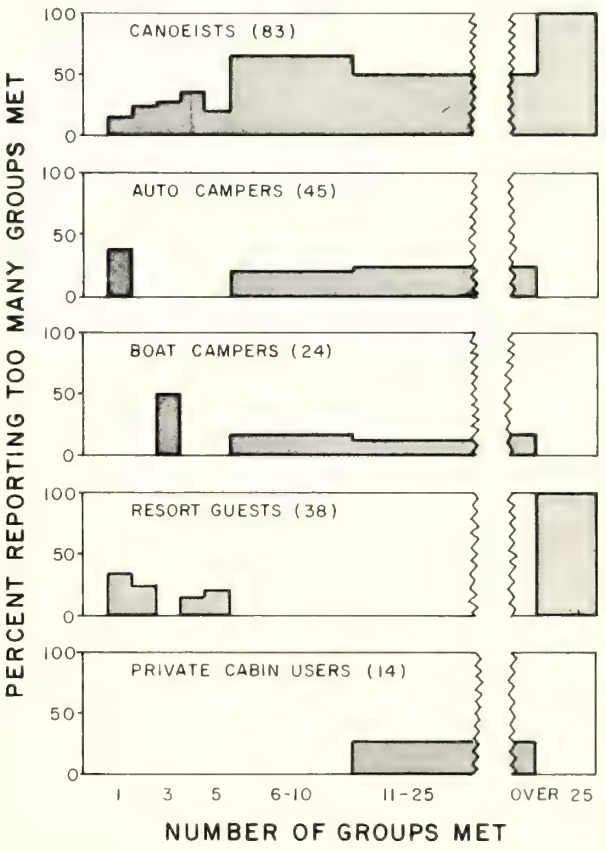

FIGURE 9. — Percentage of sample groups reporting that the number of other groups met on an average day on their visit was "too many." Number of sample groups in each visitor type is shown in parentheses.

TABLE 4. — *Opinions of crowding on lakes held by various categories of recreationists (direct question)*

Type of recreationist	Number of sample groups[1]	Percent bothered by crowding on lakes:		
		Quite a bit	A little	Not bothered
Canoeists	85	19*	18*	63*
Paddlers	64	20	20	60
Motorized	21	14	10	76
Day-users	5	0*	0*	100
Auto campers	74	7*	3*	90*
Boat campers	23	8*	8*	84*
Resort guests	57	5*	2*	93*
Private cabin users	21	5*	9*	86*
Total	265	10	9	81
Paddled canoe	92	16*	13*	66*
Motorized canoe	38	11*	5*	84*
Motor boat	144	6*	2*	92*
Total	274	10	9	81

[1] *Twenty-seven of 292 groups did not use the lakes and are excluded. Nine used more than one type of craft and are repeated in the lower half of the table.*

* *The differences between types of visitors appear highly significant. A chi-square test indicates less than one chance in one thousand of a sample of this size producing differences this large by chance.*

TABLE 5. — *Percent of recreationists interviewed at Moose Lake access points reporting opinions of crowding on lakes*

Type of recreationist	Number of sample groups	Bothered by crowding on lakes:		
		Quite a bit	A little	Not bothered
Paddled canoe	24	29	25	46
Motorized canoe	7	14	0	86
Motor boat	14	7	14	79
Total	45	20	18	62

groups could you meet in a day before you would feel there was too much use?" Canoeists usually wanted no motorboats (even those who said they "did not mind" meeting motorboats) and zero to five canoes. Motorboaters usually said "no limit" on canoeists and 25 to 100 boats. Some motorboaters seemed puzzled by the question. They apparently were not thinking in terms of seeking solitude.

The relation of amount and type of use to the feeling of being in the wilderness was studied in some detail, comparing the maps of wilderness ratings to maps of estimated use presented in a previous paper (Lucas, 1964a).

Heavily used areas were less often considered wilderness by all visitor types, especially the canoeists. Moose Lake, east of Ely, the most heavily used point, produced the following responses:

	Wilderness	*Not wilderness*
Paddling canoeists ..	0	23
Motor canoeists	2	6
Boat campers	2	4
Auto campers	3	3
Resort guests	4	0
Day-users	1	0

The lakes, or sections of rivers, reached from each access point within the study area were ranked, first in order of wilderness rating and then in order of total estimated summer use. The number of groups visiting each lake was the measure of use. Each group was counted once only on each lake visited; they were not recounted if they returned over the same route. Man-days would have been a better measure, but were unavailable. The Spearman rank correlation coefficient for paddling canoeists was —0.42; the more use, the less wilderness. This means that about 18 percent of the variation in canoeists' wilderness ratings was accounted for by season-long visitor totals. For boaters (combining resort guests, auto campers, and boat campers), the rank correlation was —0.37, accounting for 14 percent of the variation. This seems fairly substantial when it is remembered that seasonal use is only an approximate index of the number of visitors observed on a particular lake by a sample party. Furthermore, 200 groups on a lake 20 miles long and full of islands would be much less conspicuous than the same number on a narrow river, but all locations were treated identically.

This relationship between use and wilderness was graphed (fig. 10). Locations were averaged by 100-group intervals up to 400 groups, then 200-group intervals to 1,000, and then 500-group classes. The canoeists' perception of wilderness was consistently lower than the boaters', and

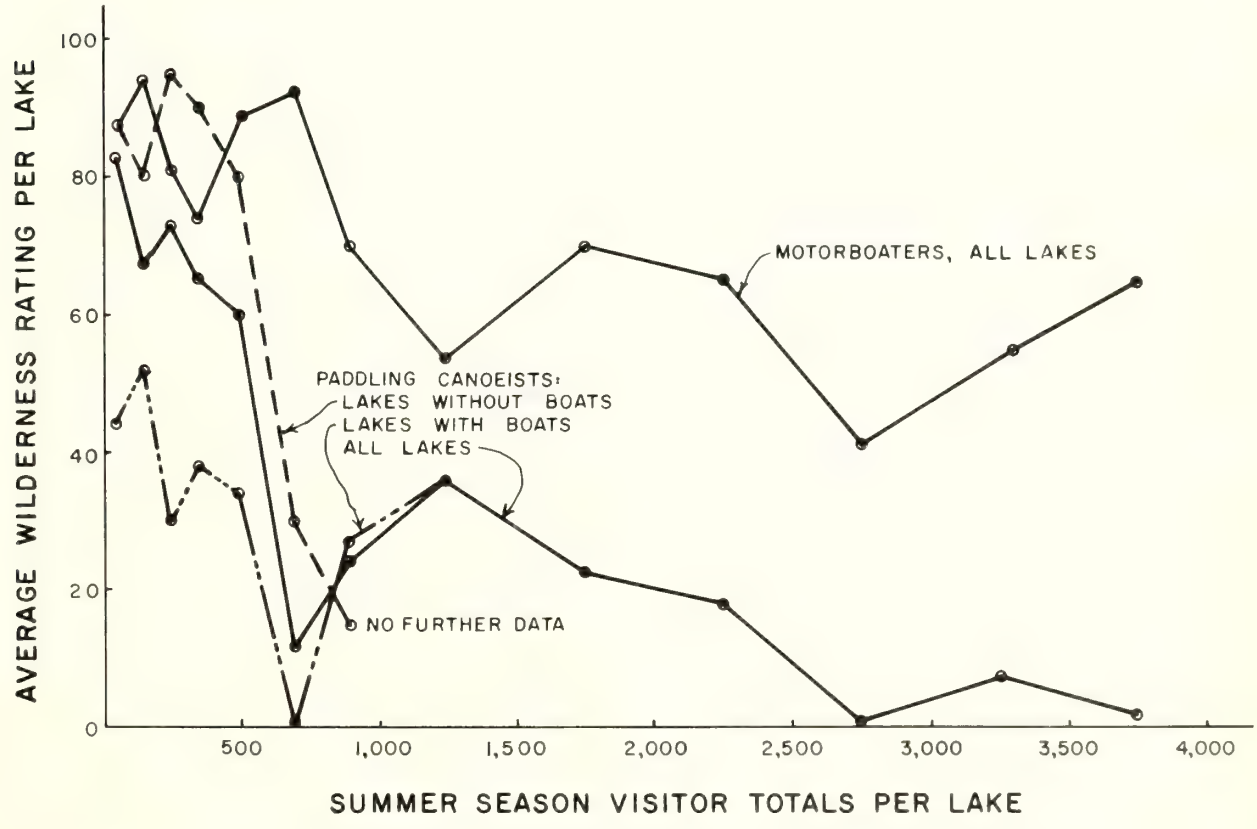

FIGURE 10. — The wilderness ratings of paddling canoeists and of motorboaters (resort guests, auto campers, and boat campers) related to amount and type of use. Each group was counted once only on each lake visited.

dropped faster as use increased. On the average, less than half of the canoeing groups considered places wilderness when group visits during the summer exceeded about 600. The line on the graph representing boaters' wilderness perception, in contrast, generally stays above 50 percent even at peak use levels.

The type of use encountered may have been even more important to paddlers than the number of groups, however. The locations used only by canoeists were separated from those used by both boaters and canoeists (fig. 10). Comparable levels of use produced higher wilderness ratings by canoeists where motorboats were absent — usually over twice as high as for places reached by boats.

The one-way resentment of boaters by canoeists was also brought out by questions on their reactions to meeting other types of groups. The paddlers distinguished sharply between all three types of transportation (table 6). They disliked meeting boats, were less resentful of motorized canoes, and apparently enjoyed meeting at least some kindred spirits paddling canoes. Motor canoeists made an equally sharp distinction between motorboats and canoes. They distinguished less between the two types of canoe parties; but still preferred meeting paddlers rather than fellow motor canoeists. Motorboaters, in contrast, were generally indifferent about whom they met. They considered motorized canoes as synonymous with motorboats, but many boaters enjoyed the local color provided by the paddlers. One can imagine people in a powerboat smiling at a group of slowly moving paddlers and being glared at in return.

One other use created even more friction — water skiing. This sport was not common in the canoe country, but there was some on a number of the directly accessible lakes and even occasionally over portages. Most people who were not water skiing wanted to see it banned in the wilderness setting (table 7). Some resort parties volunteered this as the reason they had stopped visiting resorts in Wisconsin. Auto campers were almost unanimously opposed to water skiing. Probably no single use can so drastically reduce the capacity for all other uses, and, because of the large area used by a water skier, a modest amount of skiing can have a large effect.

TABLE 6. — *Reaction of three user types to meeting other types*

Kind and number of sample groups questioned	Kind of group met on trip	Reaction of sample groups (in percent) to meeting[1]		
		Disliked	Did not mind	Enjoyed
Paddling canoists (62)	Paddling canoeists	2	26	72
	Motor canoeists	37	61	2
	Motorboaters	61	37	2
Motor canoeists (21)	Paddling canoeists	0	62	38
	Motor canoeists	0	90	10
	Motorboaters	62	38	0
Motorboaters (40)	Paddling canoeists	0	55	45
	Motor canoeists	3	72	25
	Motorboaters	3	72	25

[1] *A few groups were evenly divided in their opinions and were counted as half groups under each heading. The chi-square test indicates most of the differences are highly significant. There is far less than one chance in a thousand that the differences in either type of canoeists' reactions to different types of users resulted from chance (.001 level). In addition, motorboaters' reactions are very significantly different from canoeists, although the differences in boaters' reactions to different types are significant only at the .25 level.*

TABLE 7. — *Reaction to a ban on water skiing in some areas*

Type of recreationist	Number of sample groups	Reaction (percent)		
		Good idea	Bad idea	Don't care
Canoeists	77	77	13	10
Day-users	7	29	29	42
Auto campers	76	89	4	7
Boat campers	21	48	14	38
Resort guests	50	70	20	10
Private cabin visitors	16	63	6	31
Total	247	74	12	14

Location in Relation to Wilderness Perception

Apparently perceived wilderness need not be in Canada, nor need it involve travelling north. For example, the large block of land in the United States south of the Gunflint Trail was considered wilderness.

Remoteness or distance from access points is often thought of as a necessary feature of wilderness. The study of wilderness by the Wildland Research Center (1962, p. 119) defined wilderness recreation as use over one-half mile from a road. To test for the effect of remoteness, all of the first lakes and rivers were grouped, then the second, and so on. Surprisingly, neither graphs nor rank order correlation coefficients relating wilderness perception to use suggested that remoteness influenced ratings. Where use was comparable, lakes close to starting points were classed as wild as often as more remote places, except to some extent for organized youth groups such as Boy Scouts.

Development in Relation to Wilderness Perception

The paddlers' wilderness almost never contained roads (fig. 4) or buildings. The main exception for roads was a 10-mile stretch of the Echo Trail north of Ely. Almost half of the sample paddling groups classed this as wilderness. The road is narrow, winding, and hilly, but partly black-topped. The Echo Trail west of this section is all gravel, but is newer, fairly wide, and level, with gentle curves; no canoeists considered the area wild. In contrast, a majority of motorboaters of all types felt that the wilderness began after the last town. Road construction standards did not seem related to boaters' wilderness perception, as mapped (figs. 5 to 7), although some did mention the "end of the black-top" as the entrance to their wilderness.

Attitudes towards roads are particularly interesting as an example of opposition to what would be considered improvements almost anywhere else. This "Through the Looking Glass" reversal is particularly important in and near wild areas.

All of the access roads had narrow gravel sections where 30 miles an hour was an excessive speed. At some level of traffic, dust and driving hazards set a limit (to numbers of people and satisfaction) that can be raised only by rebuilding the roads. This is a dilemma, however, because over half of the people considered high-standard roads out of place (fig. 11). The sample groups were asked, "Do you feel that straightening and blacktopping more roads is a good idea, a bad idea, or something you don't care about either way?" The replies were:

	Number	Percent
Good idea	94	38
Bad idea	133	54
Don't care	15	6
Group divided	5	2
Total	247	100

The difference between groups that expressed an opinion was significant at the 0.10 level, tested by chi-square.

All types of recreationists were divided on this question, but a majority of canoeists, campground campers, and resort guests opposed more road "improvements," and only boat campers and private cabin visitors had a majority for "better" roads. Discussion with visitors suggested that blacktopping was less objectionable than straightening and widening.

Other facilities in the auto-accessible fringe (outside the established wilderness boundaries, but still in the wilderness for many people) were sometimes unwelcome.

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FIGURE 11. — Are roads like this appropriate as wilderness approaches? Of the visitors sampled, 54 percent said, "No;" 38 percent said, "Yes." The objections were not limited to any one type of visitor.

Most groups favored more small auto campgrounds; 95 percent of the auto campers did, and so did most boat campers and private cabin users. Resort guests were usually indifferent, but more favored than opposed additional small campgrounds. Canoeists, who seldom used campgrounds, were almost evenly divided — one-third in favor, one-third against, and one-third indifferent.

Building large campgrounds, however, was definitely a bad idea in everyone's opinion — only 12 percent of all groups and only 14 percent of the car camper groups approved. How these people defined large and small campgrounds is not known, but they seemed to feel the Superior National Forest campgrounds were small. The average for these was about 10 family units, and the largest provided for 40 groups. Many volunteered their dislike for the crowding found in large State Parks. On a free-response question, 15 percent of the auto campers listed uncrowded conditions or campsite privacy as the thing about the area which pleased them particularly, making privacy a close third behind good facilities and scenery.

Eighty percent of the visitors to campgrounds approved of installing wells or taps where these did not exist, and only 7 percent objected. Water supplies were also considered an improvement or insignificant by other groups (except canoeists, who again were almost evenly split three ways — for, against, and indifferent).

Launching ramps for boat trailers, a key factor because of their direct relation to the use of large, powerful boats, were controversial. Canoeists strongly opposed additional ramps, most boat campers and day-users favored more, and other groups were quite divided (table 8). An appreciable number in every class opposed more ramps — even those people who used motors. Some of these parties used small boats and motors, which did not require ramps, and they disliked the powerful boats almost as much as did the canoeists.

Within the areas accessible only by water, different facilities are of interest. Canoe campsites, as we have said, were fairly adequate in number. An open question on desired changes produced re-

TABLE 8. — *Reaction to the construction of more launching ramps*

Type of recreationist	Number of sample groups	Reaction (percent)		
		Good idea	Bad idea	Don't care
Canoeists	77	10	74	16
Day-users	7	57	29	14
Auto campers	76	49	39	12
Boat campers	21	60	21	19
Resort guests	50	46	32	22
Private cabin visitors	16	37.5	37.5	25
Total	247	37	47	16

quests for more campsites from only about 1 percent of the sample. People who used these sites were satisfied with and in many cases preferred very simple facilities. Canoeists more often asked that the picnic tables on back-country sites be removed than that more be added. More tables were wanted by 17 percent of the boat campers, however. None wanted water supplies other than the lakes.

Portages were the other main facility. On the free-response question about desired changes, 11 percent of the canoeists and 1 percent of the auto campers asked for better portage marking. (Many portages in the Boundary Waters Canoe Area have a small Forest Service sign giving the names of the lakes and the distance, but most of those in Quetico Park have only blazed trees.) Only 1 percent of the canoeists and resort guests and 4 percent of the boat campers called for other portage improvements. Later, when asked directly about portage quality, a majority of all types of visitors said they liked the portages as they were. More than three-fourths of both canoeists and other visitors said the portages in the United States should be left about the same; 3 percent of the canoeists and 6 percent of the others said the portages had already been over-improved. The remainder, less than one-fifth, wanted some improvements. The rougher Canadian portages were not quite as popular, but 62 percent of both types of visitors said they should be left as they were. Less than a third wanted improvements in Canada.

Nonrecreational Use in Relation to Wilderness Perception

Another set of attitudes centered on nonrecreational uses of the area. Logging, especially, has been vehemently objected to for western wilderness areas, as well as in the Boundary Waters Canoe Area. But the problem appears to be overrated in the Canoe Area, at least as far as the visitors are concerned (Lucas, 1963). First, there was little awareness that timber cutting was carried on in the area. Of the sample visitor groups, 42 percent said they did not know if logging was allowed in the Boundary Waters Canoe Area; 28 percent said logging was prohibited; and only 30 percent gave the correct answer. Of the visitors in the general vicinity of logging operations, 51 percent gave the correct answer. Still fewer noticed logging or recognized it when they saw it. Only 18 percent of all visitors thought they had observed logging in the study area. Near cutting areas, 46 percent reported observations (table 9). Canoeists, who covered more of the area than other groups, reported proportionately fewer observations than the predominantly boating types.

TABLE 9. — *Visitors' reactions to logging*

Area and type of recreationist	Number of sample groups	Percent of groups who—		
		Did not notice	Noticed, no objection	Noticed, objection
Areas remote from logging				
Boaters[1]	138	84	12	4
Canoeists	69	94	3	3
Total[2]	207	87	9	4
Areas near logging				
Boaters[1]	31	48	39	13
Canoeists	9	75	12.5	12.5
Total[2]	39	54	33	13
Total, for all areas:	246	82	13	5

[1] *"Boaters" refers to the total for all noncanoeist user types.*

[2] *Total numbers reporting noticing logging in the areas near cutting differ significantly from the areas distant from logging at the 0.001 level, tested by chi-square.*

Probably fewer visitors observed logging in the Boundary Waters Canoe Area itself because the question included some of the surrounding area. Many observations may have been reported because logging trucks were encountered, or piled pulpwood was seen on access roads.

Further, even when logging was observed — or when people thought they had observed it — they often did not object to it. About 30 percent of those who said they had observed logging were bothered by it. In the areas near logging this was

only 13 percent of all visitor groups. The canoeists, who in most other respects were also the most sensitive class, objected most often to logging when it was observed (half of the cases), but this was only 4 percent of the total interviews (13 percent in areas near logging) because of their very low rate of observation. In contrast, almost all canoeists encountered boats, and two-thirds objected, suggesting that conflicting types of recreation are a more serious problem at present.

THE CAPACITY OF THE QUETICO-SUPERIOR AREA

In 1959 the Forest Service, in connection with a nationwide survey of recreation resources, estimated the capacity of the Boundary Waters Canoe Area. They estimated subjectively that 1.75 acres (land and water) were necessary for each visitor-day per year, indicating a total capacity of about 600,000 visitor-days. This would permit about a 50-percent increase in use over 1961, when the estimated visitor-day total for June 11 through September 9 was 319,000 and for the entire year about 400,000. No assumptions were given as to the composition of use or the level of satisfaction, except the clear implication that this level of use would provide a generally satisfactory wilderness experience.

In the study conducted by the author in 1960 and 1961, sufficient data on use and visitors' attitudes were collected to permit some estimates as to what, in the visitors' opinions, constitutes overuse. These estimates are based on specific assumptions. The assumptions and estimates are presented below.

Assumptions Made in Defining Capacity

The capacity of any recreational area is a complex concept;[6] specifying its magnitude, even very generally, requires a number of assumptions. One set of assumptions involves satisfaction — how much satisfaction for whom? The variation in sensitivity to crowding both within and between user types eliminates any simple standard, either of amount of use or its composition. For example, maximizing the canoeing capacity of the Boundary Waters Canoe Area would require reducing the motorboating capacity to zero; and maximizing the motorboating capacity would eliminate wilderness canoeing. Furthermore, using the interior areas to capacity would lead to overcrowding of the trunk routes used to get there. How should such areas of overuse and underuse be balanced? A similar problem exists with peak periods of use.

Against this background of difficulties, capacity will be considered first in terms of the present combination of uses; then the possible effect of eliminating motorboats from some of the area will be investigated.

Our first assumption is that the paddling canoeists are the critical group in establishing the area's capacity. As the name Boundary Waters Canoe Area indicates, and as the 1948 plan of management makes clear, canoeing under wilderness conditions is the top priority use, with motorboating at best tolerated where it is already firmly established. Since canoeists consider areas overcrowded at much lower levels of use than do any other types of users, full capacity for canoeists would be less than full capacity for others.

The graph relating use to wilderness perception of the paddling canoeists (fig. 10) indicated that on lakes without boats, almost all the canoeists felt themselves in the wilderness if use was under something around 300 groups for 3 months. Also, meeting one party a day was acceptable to 83 percent of the canoeists, and 77 percent could take two groups a day. In an area (a large lake or group of small lakes) used by 300 groups during the main summer season, the expected frequency of encounter would probably be between one and two parties per day. Where motorboats also used the lakes, even the most lightly used lake was considered wilderness by only about half the canoeists, and most canoeists said they could not meet any motorboaters without loss of the wilderness atmosphere. Again, these two measures seem consistent. Both of these thresholds are approximations at this stage and should be regarded only as indicative of the general range.

[6] *For a general discussion of this problem, see Wagar, 1964.*

It is estimated, then, that the threshold of overuse is reached in most areas without boats when they are visited during the season by more than 300 groups of canoeists. This is the threshold at which "full wilderness" begins to be lost. "Most areas" is specified because some variation is probably desirable; some areas should probably be visited by only 100 groups or less, to provide places for people who value solitude highly. However, even if all access points were used by 300 canoeing groups, there would still be many areas within 2 days' paddling where other canoeists would seldom be met, particularly at times other than the peak period from the 4th of July through Labor Day.

Our second assumption is that use on the first two lakes on each route could exceed the appropriate threshold. Because most routes branch off fairly soon, maintaining low use at access points would produce more underused interior area than seems necessary or desirable. The lakes beyond the first two were taken as critical; if they had under 300 groups of canoeists and no boaters they were considered underused, and the same designation was applied to the lakes leading back to the access point, regardless of their amount of use. (If the canoe route branched so that there were two or more third lakes and only one was overused, then the first and second lakes leading to both were classed as overused.) Sections of rivers separated by portages were treated as lakes.

We have defined a "full wilderness threshold;" a second, "half wilderness threshold," can also be specified. Half of the canoeists said the wilderness was lost on lakes used by about 600 groups of canoeists (this figure is based on few observations and is presented very tentatively). Where motorboats were found, half the canoeists felt that the lakes were no longer wilderness if used by, at most, 200 canoeing and boating groups combined. These levels also seemed of the same general magnitude as the answers to the direct questions about reaction to numbers met daily. A majority of canoeists complained if they met more than five canoeing groups a day, which would appear as a reasonable expected frequency of encounter for a lake or group of small lakes used by 600 parties during the study period. A lake used by 200 groups, if roughly half were motorboaters, would also seem likely to produce at least one encounter per day with a boat party. Areas beyond the first two lakes where use exceeded these limits were classed as overused.

Lakes and streams used by numbers between the upper and lower limits were classed as transitional. A majority of the canoeists considered such areas wilderness, but many did not.

The thresholds and the classifications of areas can be summarized as follows:

Area classification	*Type of use*		*Level of wilderness*
	Canoes	*Boats and canoes*	
Underused	less than 300	none	"Full wilderness"
Transitional	300-600	1-200	"Half wilderness"
Overused	over 600	over 200	Not wilderness

To repeat, these definitions were applied beyond the first two lakes.

Lac La Croix was singled out for special consideration because it is so irregular and so much larger than any other lake, and obviously could accommodate more users than the average lake. Lac La Croix was directly classed as transitional (it received a 67-percent wilderness score).

The Distribution of Underuse and Overuse

On the basis of the definitions discussed above, large areas in the Quetico-Superior area appear underused (fig. 12).[7] Except for the route north from Basswood Lake, most of Quetico Park was underused. Overuse was more widespread in the Boundary Waters Canoe Area, particularly in the areas east of Ely. The Little Indian Sioux River to the west appears on the map as overused, but this effect was caused by a small amount of boat use. Some important accesses were underused (fig. 12): The Moose River, the Indian Sioux River upstream (south of the Echo Trail), the Stuart River, Nels Lake, Fenske Lake, Crab Lake, the Isabella River, Kawishiwi Lake, Baker Lake, Brule Lake, and Gunflint Lake. The other access points were in the transitional range, although many of them led to some underused routes.

[7] *Throughout the remainder of the study the terms "underused," "transitional," and "overused" will mean as defined in the suggested evaluation scheme presented here, and the modifiers and cautionary warnings will be understood.*

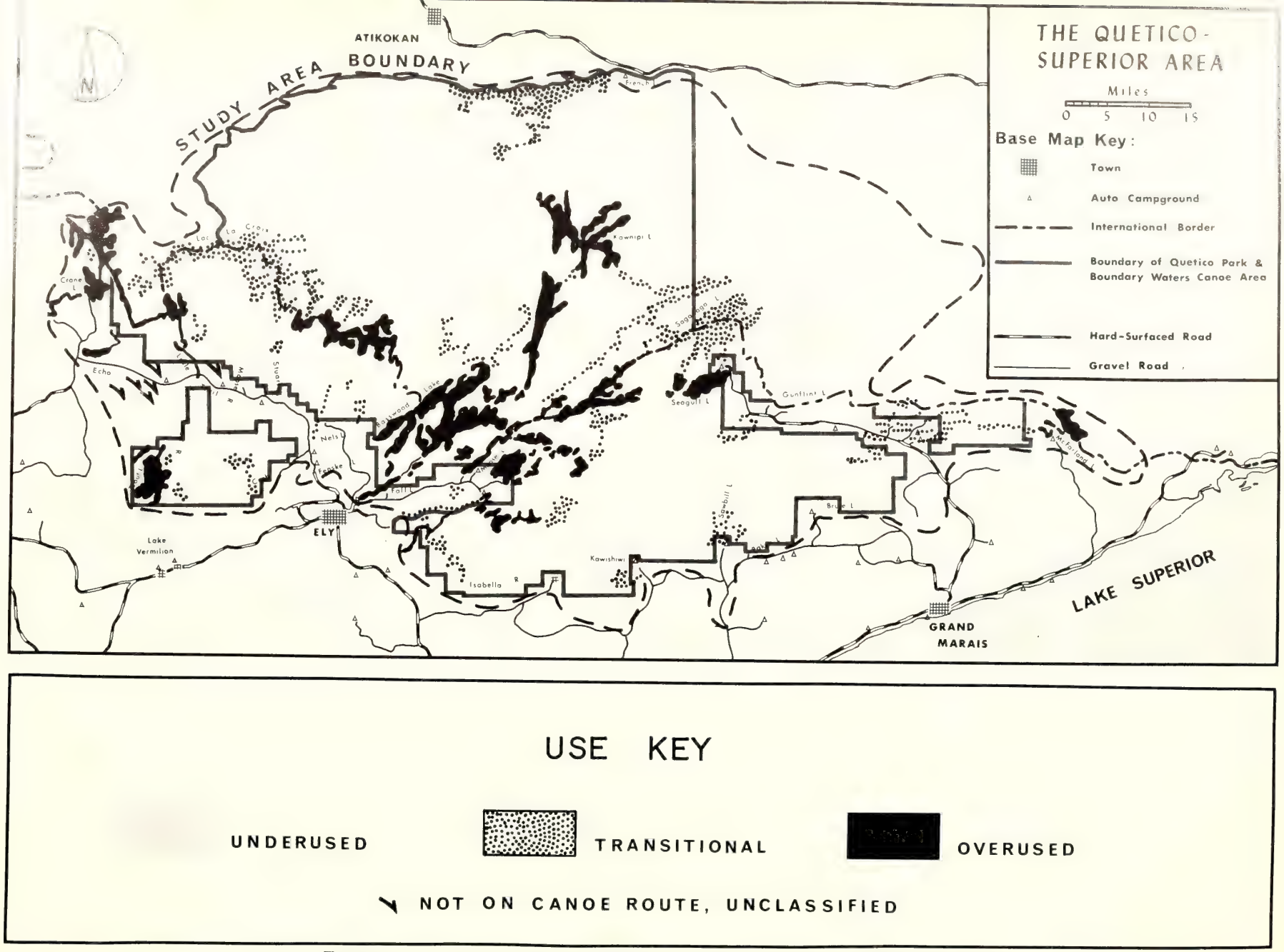

FIGURE 12. — Use in relation to wilderness capacity, June 11 to September 9, 1961.

A comparison of the stricter thresholds (essentially full wilderness) with the amount of use on the underused routes, suggests a potential for about a 55-percent increase in visitors to the Quetico-Superior (over 42,000 additional people). For the Boundary Waters Canoe Area, this would allow for about a 60-percent increase in visitors, with the same combination of types of use, but with a change in distribution as a result of increasing use where it is now light. This only slightly exceeds the National Forest estimate of a 50-percent increase to reach potential capacity.

However, a reduction of visitors in the overused areas to at least the levels at which about half would consider the area wilderness, would almost cancel out the unused capacity; it would allow a net increase of only 5 percent for the whole Quetico-Superior and almost nothing for the Boundary Waters Canoe Area.

It should be stressed again that these results are tentative and that they also depend upon tolerating overuse of the first two lakes on each route. If overuse were accepted on the first three or four lakes, capacity would increase.

If motorboats were eliminated from all areas beyond the second lakes in the Boundary Waters Canoe Area and Quetico Park, the capacity of the area would apparently be increased greatly. If the number of visitors were reduced in the overused areas to the half-wilderness level, and increased in the underused areas to the full-wilderness threshold, net capacity would exceed use by about 50 percent, instead of only 5 as with the present distribution of boats. At a high standard of wilderness environment, the Boundary Waters Canoe Area could still have its use increased about 40 percent instead of almost no expansion under the present mixed boat and canoe conditions.

THE RELATION OF TRENDS TO CAPACITY

How soon might some of the critical use levels suggested in the preceding section be reached, if recent trends persist? This is an important question, but the answer must be qualified. The critical use levels were only first approximations of a difficult measure and inevitably involved certain arbitrary choices. Standards for wilderness could change in the future. Furthermore, the past trends were not very clear, so that any projection should be viewed with even more caution than projections in general.

However, if we make the best of a not-too-good situation and use the figures at face value, it appears that time is short. If all of the future increase in use in the Quetico-Superior could be shifted to the underused points, the full-wilderness level would be exceeded about 1965, based on the past 12-percent annual rate compounded (Lucas, 1964a). The next point, "half wilderness," would be passed only 3 or 4 years later (1968-69). Both these figures are gross in that they assume no reduction at overused points. The dates for the Boundary Waters Canoe Area alone are the same.

Net capacity — capacity after overused areas have been reduced to the upper level — would be reached sooner, of course; even at half-wilderness levels, capacity would be exceeded by 1967. The full-wilderness level was probably exceeded in 1962.

If use of all accesses should increase at the same rate, the underused points as a group would not reach the full-wilderness threshold until about 1975, and the half-wilderness level in 1982. Of course, in 1982 Moose Lake would be visited by about 200,000 people, an almost incredible situation. Before this could happen, undoubtedly many visitors would shift to the more lightly used places and thus shorten their period of grace.

The more reasonable expectation seems to be that full-wilderness capacity generally would be reached between 1965 and 1975, and half-wilderness between 1968 and 1982, if increasing use and resulting dissatisfaction do not depress the rate of increase. But the 12-percent rate can hardly continue; if it does, by the year 2000 over 6,000,000 people will seek solitude in the Boundary Waters Canoe Area.

If motorboats were excluded from the wilderness core, capacity would not be reached as soon. Even then, the deadlines would be moved back only about 3 years because of the rapid increase in numbers of visitors.

SUMMARY

The Quetico-Superior wilderness lakeland has been both preserved and restored. It was one of the earliest areas of wilderness preservation; the two halves of the area, one on each side of the international border, were both established in 1909, and the value of their wilderness character was officially recognized by the 1920's. Inappropriate uses have been progressively restricted since then. The area has considerable social utility because of its location relatively close to the major population concentration of North America, but this proximity also raises the possibility that recreational use will increase until the wild quality is lost.

Capacity — the number of visitors and their degree of satisfaction — seemed to be more a function of attitudes than of physical factors. Attitudes seemed to be related to the craft used — boat or canoe. Canoeists were seeking wilderness, viewed a small area as wild, wanted this area kept undeveloped, and disliked heavy use. However, canoeists seemed willing to accept roughly three times as much canoe use as mixed boat and canoe use. Among other user types, none cited wilderness as an attraction in over half the interviews, although auto campers came close to this level. All user types except canoeists saw a large area as wild, were tolerant of relatively heavy use, and did not differentiate particularly between types of visitors encountered. The friction between users of boats and canoes was thus a one-way affair.

If the assumptions made for measuring capacity in this study are acceptable, then total use in 1961 was only about 5 percent less than total capacity. Because of the unevenness of the distribution of use, however, large areas could apparently be used more often without a loss of wilderness qualities, while severe overuse is found elsewhere. A 55- to 60-percent increase in total use would probably not seriously detract from the wilderness environment if it all occurred at the underused accesses. Eliminating motorboats in the interior would apparently make possible an 80- to 90-percent increase in use.

When past trends are projected and compared to capacity, serious problems appear not too distant. If no access could be overused, full wilderness capacity has already been exceeded. A more realistic estimate places the disappearance of full wilderness between 1965 and 1975. The earlier deadline assumes all increases take place at presently underused areas, and the 1975 date assumes no relative change in distribution. Both dates assume no restriction of motorboats, are aimed at satisfying the paddling canoeists (the most demanding group), and assume adequate provision of access point facilities, such as parking. Levels of use considered consistent with wilderness by the less demanding half of the paddling canoeists would be experienced only a little later — between 1968 and 1982. There would still be some underused access points, lightly used interior lakes, and fewer visitors in spring and fall even in 1982, if the present relative distribution in time and over the area did not change substantially. In effect, if use continues to climb, the wilderness, like a shallow desert lake drying up, will first retreat to the interior, then break up into small isolated areas, and finally disappear, first for canoeists, and considerably later for other types of visitors.

MANAGEMENT IMPLICATIONS

The results reported in this study do not, in themselves, determine the best or right management policies. Assumptions about ends and means are necessary. The ends, in this case, have already been discussed: the provision of a wilderness experience without unnecessary limitation on other economic activities. For the Boundary Waters Canoe Area, the goal is further specified as a wilderness canoe trip experience. These are established goals of public policy, independent of this study.

A Framework for Recreational Policy

The following assumptions concerning the choice of means of reaching outdoor recreational goals have been made:

1. The right to choose a type of recreation must be respected, whether the choice is water skiing or canoeing. This does not mean value judgments may not be made; it does not bar efforts to encourage free choices of more appropriate forms of recreation.

2. A range of recreational opportunities must be provided from which people may choose. This range should ideally be present within an area small enough to provide effective choice; put differently, Alaskan wilderness is not a satisfactory substitute for wilderness in Minnesota. On the other hand, the whole range cannot be available at every location; auto sightseeing and roadless wilderness are mutually exclusive, for example.

3. The provision of a range of recreational opportunities within a large area should take account of the demand for each alternative activity and the requirements of each activity in terms of participants' standards (for such things as the physical characteristics of the area, facilities provided, and other uses of the area, including other types of recreation). Furthermore, to determine the extent of the area needed for each type of recreation, managers must know how users distribute themselves, how use of an area is affected by accessibility to the population, and how best to separate or integrate different types of recreation.

4. In addition to these aspects of demand, the range of opportunities to be supplied should also be based upon knowledge of the number and size of suitable areas — suitable according to the users' standards. Technical feasibility, such as for sanitation or erosion, is also a necessary condition or limiting factor. The types of recreation with the fewest alternative locational possibilities should have priority for the use of a particular area, if other things are equal.

5. Recreationists must know of alternatives — alternative activities and alternative locations — if the free-choice system, which is assumed to be preferable, is to operate in a socially efficient way.

6. Direct regulation of what is meant to be a free and pleasurable part of life is unfortunate, and should not be employed if there is any other way to achieve the desired end.

The Quetico-Superior presents a distinct choice within the range of recreational opportunities — canoeing under near-primitive conditions. It is a choice near one extreme, and although no part of the range is necessarily intrinsically better than any other, this particular opportunity seems to serve a large and growing demand, faster growing than the demand for conventional recreation. It is certainly a minority demand, but the area dedicated to it is only a small part of the Upper Great Lakes region. Canoeists' attitudes indicate that motorboating is incompatible with canoeing in a wilderness, and without priority the opportunity to choose wilderness canoeing would be reduced or lost. The priority is justified for two additional reasons. First, the wilderness qualities of the area were more important to the canoeists than to other groups. Second, a map of recreational areas shows that the canoeists have fewer alternative locations. Visitors also saw the matter in this light. All parties were asked, "Are there any other parts of the United States or Canada which you would consider as suitable for the activities you like to do here?" There were no reported substitutes for 78 percent of the paddling canoeists, 62 percent of the motor canoeists, and 57 percent of the other visitor classes.

Major Present Policy Problems

If the present use of the Quetico-Superior is evaluated in relation to the given policy objectives, one central problem stands out: redistributing

use. There are two aspects to this redistribution: first, shifting at least some people from heavily to lightly used areas, and second, separating conflicting uses, which primarily means keeping motorboats away from canoes. Separating the motorboats from the canoes may be more important; one motorboat seems to equal at least three canoes, from the canoeists' point of view, partly because boats destroy their wilderness and partly because motorboats will be observed by far more groups than will canoes because they travel farther and make more noise. Simply dispersing all use to reduce local crowding without separating the two incompatible types would appear to be a mistake; instead of solving the problem it makes it more widespread.

Separating motorized canoeists from paddlers is a less serious problem, although it affects a larger area.

Limiting the amount of use is not now a major problem, except locally, but within 10 years the situation will probably become critical. Even now, a thorough redistribution of use would leave no unused capacity unless boats were excluded from the interior.

A Suggested Approach to Use Separation and Dispersal

Separation

A possible approach to use separation seems to be a system of concentric zoning. The recreational development of the Border Lake region already has a concentric quality — first comes the developed fringe, then the wilderness used for timber production, and in the core the no-cut zone — but this ring approach has additional potential.[8]

Concentric zoning may have possibilities for increasing the satisfaction of the canoeists, who are more sensitive to crowding and competition, without decreasing the satisfaction of the other, less sensitive, motorboating visitors. Two factors especially seem to make concentric zoning feasible: (1) motorboaters view a much larger area as wilderness than do canoeists, and (2) the distributions of the two uses are quite different. Although it may be justifiable to assign priority to canoeists in the Boundary Waters Canoe Area, this does not mean that boaters need to be excluded from all of their wilderness. Three zones are suggested:

1. *The general recreation zone.* — This is the outermost zone. It would permit and encourage a wide range of activities that do not require a wilderness setting and that are largely incompatible with those uses depending upon the wilderness environment. This is the place for water skiing on large lakes and for using 100-horsepower motors. Although this area has not been studied, tolerable use levels are probably high. At present, all land outside the Boundary Waters Area and Quetico Park is, in effect, so zoned.

2. *The "wilderness" motorboating zone.* — This zone does not now exist. It lies inside the general use zone, closer to the wilderness core. It might correspond roughly to the area outside the Boundary Waters Canoe Area, which over half of the various boating classes considered wilderness (fig. 8); it was seldom visited by canoeists, and they did not think of it as wild. The outer part of this belt lies outside the study area, and visitors there were not interviewed. Consequently, the boundary between this wilderness boat zone and the general recreation zone is undefined at present.

Wilderness motorboating ("wilderness" in the boaters' terms) could be vigorously encouraged here. The zone could even be given a name, perhaps something like, "Superior Motorboat Backcountry." Most new auto campgrounds and all new boat access points would be developed in this zone, rather than at the end of the roads where the canoe routes begin. (Most boaters did not consider campgrounds and launching ramps inappropriate in a wilderness.)

There are lakes in this zone with few or no access or camping facilities; these could provide a high level of enjoyment for many motorboaters without detracting from anyone else's pleasure. Some lakes have resorts and private cabins but no campgrounds and inadequate public access. Other lakes now have very little use of any kind, and could be developed for a more primitive type of motorboating. Some in this last group could be

[8] *Concentric zoning has also been suggested generally as an approach to regional recreation planning (Carhart, 1961; Outdoor Recreation Resources Rev. Comn., 1962; and Wildland Res. Center, 1962, p. 303). The relation of access to concentric zones is critical, however. Visitors desiring the inner zones might be forced to travel through outer, to them unattractive, zones, thus defeating the very purpose of zoning — separation of incompatible uses.*

zoned to exclude buildings, and could be developed in part for boat camping away from the road ends.

Confining new developments to this zone conforms to the Forest Service policy of excluding motorboating within the Boundary Waters Canoe Area where boating is not well established.

To further preserve a genuine opportunity for a wilderness experience for boaters, very large, powerful boats and the associated activities should probably be eliminated here. However, the Forest Service may lack authority to directly control navigation, which is a function of the State government. Minnesota State Parks, for example, regulate boat power and speed.

Apparently boaters willingly accept a relatively high level of use in their wilderness; therefore, the use potential of this ring is probably high — high enough to absorb the increasing boating use under high-quality wilderness conditions in the foreseeable future, especially since boating is not expected to increase as rapidly as canoeing.

3. *The Boundary Waters Canoe Area.* — This zone's boundaries have already been administratively defined. Wilderness canoeing is the top priority use and would be the only use encouraged. New launching ramps for trailered boats and most campgrounds would go in the second zone, not here. Much of the Boundary Waters Canoe Area is now used by motorboats; in fact, much of it is dominated by boats (**Lucas, 1964a, Plate XI**). If the goal of maintenance by the Federal Government of one place in the United States for wilderness canoe travel is taken seriously, this boat use seems undesirable since motorboating is incompatible with wilderness canoeing.[9] Exclusion of motorboats generally within this zone may not be necessary immediately, but it does seem desirable to limit the use of motorboats on interior lakes in the Boundary Waters Canoe Area. This limitation need not be by direct policing. It is the truck and rail portages that make possible the heavy boat use — in fact, boat use almost cuts the Boundary Waters Canoe Area off from Quetico Park. If the mechanized portages are left, public money spent to remove resorts and cabins in order to eliminate inappropriate recreational uses will have been ineffective.

The storage of boats over portages where the land is federally owned will soon be prohibited. Enforcement of this regulation should reduce the penetration of motorboats into the interior.

The rapid decline in boat use over unmechanized portages would indicate that if the truck and rail portages were eliminated and if boats were not stored within the Canoe Country, the friction zone could be reduced to little more than the first and second fringe lakes, which canoeists quickly leave behind.

A map showing the areas where boat use is not established and is therefore prohibited under established policies would help implement the policy.

A restriction on outboard motor power seems even more necessary and justified within the Boundary Waters Canoe Area than in the proposed motorboat wilderness zone. Large motors[10] are unnecessary for fishing, sightseeing, or boat camping — the only boat uses enhanced by a wilderness environment. Not only canoeists, but also many motorboaters would welcome a size limit.

Separating the canoeists who use motors from those who paddle may also be desirable, though less urgent. But such separation is not as easily achieved as for motorboaters; areas of use overlap much more. This problem is not expected to intensify quickly, since motor-canoeing seems relatively slow growing. The Boundary Water Canoe Area policy permits the use of motors on canoes "on the main routes where such use has become accepted as a common means of transportation" (U.S. Forest Serv., Superior N. F., 1948, addendum). The map in the previous study (Lucas, 1964a) showed large areas where motor canoes were scarce; these data could serve as a guide for implementation of the policy. If a no-motor area were established, it could be considered either a fourth zone, similar to the interior no-cut zone, or a sub-zone of the Boundary Waters Canoe Area.

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[9] *Motorboat use is also considered to be the major detraction from the Canoe Area's wilderness qualities in the Wildland Research Center's study, 1962, p. 10.*

[10] *Resorts rent motors up to 10 horsepower but rarely larger. About 32 percent of the motors used by sample parties were 12 to 75 horsepower. Boat campers and private cabin users were the only types frequently using large motors.*

This three-zone approach seems to be generally consistent with the findings of this study. It should reduce the conflict between boating and canoeing, or at least limit its spread and intensification. At the same time, it seems to meet the requirements and desires of most boaters as effectively as access to the heart of the Canoe Country. The differing wilderness images are not the only findings supporting this conclusion. A second, the fact that wilderness qualities were less important to boaters than to canoeists, has been mentioned. Fishing outranked wilderness as an attraction for boat campers, resort guests, and private cabin users. Scenery also took precedence over wilderness for resort guests and private cabin visitors. Third, boaters had less definite reasons for choosing their routes, and even were sometimes uncertain where they had been; therefore, there should be little reduction in satisfaction associated with using one lake rather than another.

The same general zoning approach would probably be suitable in Canada.

The Feasibility of Concentric Zoning

The findings of this study also suggest that the zoning approach is feasible, although not without problems. The use distribution analysis in the previous study (Lucas, 1964a) suggests that the wilderness boat zone development would be most successful and deviate least from present use patterns for auto campers, whose use was only weakly related to location characteristics. On the larger lakes particularly, if wells were provided, substantial use and high satisfaction would be expected. In fact, even on small lakes, if drinking water is provided, as much use per campsite as is usually thought desirable would be expected. This ease of redistribution is fortunate because auto camping seems to be rapidly increasing. The lakes of the proposed wilderness boat zone appear to have ample capacity for a large number of auto campers, especially if several small- or medium-sized campgrounds were located on larger lakes.

On the other hand, redistribution of auto campers would not provide as much relief for the canoe campers as their number would indicate. Auto camping is not as incompatible with canoeing as some other types of use; it is extremely peripheral and the least boat-oriented of any recreation uses except canoeing.

Boat camping would probably be less easy to shift because it is less dependent upon a fixed development than is auto camping. Furthermore, boat campers have pronounced likes and dislikes. Lakes away from Canada — even if large, on major routes, and with direct access —were not heavily used. Small lakes were rarely used. However, the Crane-Sandpoint-Namakan Lake Area, already the most popular location for boat camping, is in the proposed boat wilderness zone; and here and on huge, complex Rainy Lake the potential for expansion is great. In addition, Lake of the Woods and many lakes in Canada provide excellent alternative areas for boat camping. The resistance to shifting use is unfortunate because this class of visitor penetrates fairly deeply with powerful boats, and is therefore more incompatible with canoeing than most other types. However, the expected rate of increase is low.

Any effort to encourage prospective boat and auto campers to use the outer lake zone will require making them aware of the alternative areas through maps, pamphlets, road signs, newspaper articles, and the like. These groups are above average in education, especially the auto campers, and should be able to make good use of the information. Without these aids, they are not likely to sort themselves out in a way consistent with the land management goals.

Day-use is so strongly related to the distribution of population that shifting it much would be difficult. However, it is a minor use, and its growth is slow.

Resort and private cabin use depends largely upon privately owned land, but is subject to some control by the public agencies. The counties have general zoning authority, and within the Boundary Waters Canoe Area the Forest Service has authority to eliminate these two types of use of private land. Outside the Canoe Area, the Forest Service has leased sites for both cabins and resorts, but has generally stopped issuing new leases.

Nearly all canoeing is already within the inner zone, and no change is necessary to separate uses.

In addition to informing visitors of alternative areas, an education campaign to suggest alternative ways of viewing the resources of the area might be worthwhile. For example, a view that is broader than fishing and that includes contemplative travel

through wild, scenic areas as an end in itself could be presented. Conceivably, some speedboating might be tempered by pointing out the special character of the area and the basis for canoeists' objections. A number of motorboaters indicated no knowledge of the existence of the Boundary Waters Canoe Area and its policies, and almost all seemed unaware of the canoeists' resentment of them. Motor canoeists may have overestimated the difficulty of paddling a canoe and overlooked the advantages, such as quiet observation of wildlife and lighter loads on the portages.

Dispersal

Dispersal of users — reducing the extremes between overuse and underuse — is apparently needed at this time only for canoeing. No other use is so unevenly distributed at access points. Although canoeists' use declines slowly away from the starting point and covers all of the area, even in the interior the variation in the number of visitors is extreme. Also, only canoeists seem sensitive enough to present levels of use to be dissatisfied.

The optimum canoe use distribution probably is not a perfectly even spread over the entire area; visitors differ in their perception of crowding. An even spread, in fact, is impossible because of the branching pattern of routes; diversity would exist in the interior even if use of all access points were uniform. However, extremely light use seems unnecessary if enough campsites are available to avoid excessive wear and tear because of concentrations of visitors. Thus it seems that increasing visits to most of the underused areas of figure 12 is desirable. It would probably also be desirable to reduce the number of visitors to the few very heavily used areas; these groups do not appear to be any less sensitive to crowding than other canoeists.

The number of lightly used access points was substantial. Their site and relative locational characteristics were different from those of the popular places. Encouraging modest increases in visits at these little used places seems possible in two ways: first, more people could be informed about the alternative areas. Many visitors are aware of only a few starting places and routes. Canoeists probably would make good use of information such as a map and description of access points and maps of intensity and type of use. The Superior National Forest map shows routes and describes 10 of them, but very few sample groups knew about this map. The new Forest Service Visitor Information Center in Ely may improve visitors' knowledge of alternatives substantially.

Second, some of the characteristics of the locations could be changed. Perhaps permission could be granted for an outfitter's outpost at an underused access point — a place where canoes could be stored, and where an attendant could check cars, at least periodically, to control the occasional senseless vandalism. At some lightly used points where access from the parking area is by a long initial portage rather than directly from car to water, the portage might be shortened. Eliminating the portage altogether might not be wise, however, for three reasons. First, when access points were grouped into classes with similar locational characteristics except for direct access, half of the classes showed greater use where canoes had to be portaged to the water. Second, eliminating the portages could open the areas to boat use, which is very light where direct access is not provided, and thus eliminate the only places where a canoeist can usually escape boats at the start of his trip. Third, elimination of portages reduces the effective wilderness area.

Relative location is also subject to directed change. Canada and Quetico Park are fixed, but the customs and Park entry points are not; changes in their location could help redistribute use in both countries. At present, canoeists cannot legally enter the Park between Crane Lake and Basswood Lake, and on Basswood the location of the second entry point in the central part of the lake (fig. 3) is awkward for canoeists (although well located for the remaining resorts). It is understood that Canadian officials may move this second entry point to the west on Basswood Lake after the removal of all resorts. If this is done, visitors could use several routes to Quetico more effectively. If, in addition, a customs office could be added to the eastern Lac La Croix Ranger Station, the routes on the three rivers crossing the Echo Trail would become more attractive and more canoeists could enjoy the lightly used western part of Quetico Park, rather than all crowding through Prairie Portage.

New access points for canoes could help to change use patterns, but with so many existing

points used so little it does not seem to be a pressing need, with two possible exceptions: One is in the west, where most of the area south of the Echo Trail lies almost unused. Public access to this area is very poor from the southeast, a natural entry point. The other area is west of the Gunflint Trail. A number of rarely used good routes go south and west from Poplar Lake especially, which has many resorts but no public access.

Small lakes in general, or small rivers, might be considered for any new canoe access points. Few boats used such waters, even where there was direct road access. Canoeists did not use the small lakes much either (they used the rivers more), but an access point on a small lake leading to an attractive, lightly used area might draw the desired amount of use, say 200 groups a season, if canoeists knew about it.

One other means of providing an opportunity for canoe camping in solitude — cutting new portages to the many smaller lakes off the "through routes" — is already being pursued, and seems useful. But canoeists should be informed of these possible side trips; most of the current maps tend to emphasize the main routes, and available navigational maps are 10 years out of date.

Besides education and changes in the area, direct limits on numbers of groups admitted could lead to a major redistribution if each access point had a quota. The general question of direct limits will be considered in the next section.

Other Policy Considerations

Conclusions from the study apply to other policy decisions besides those relating to the main problem of use distribution and separation.

Limiting Amounts of Use

There may be some Malthusian-type of minimum-satisfaction carrying capacity, beyond which discontent stops increased use, at least of the types for which the area is intended. This appears as unattractive as Malthusian population control. Other controls of use seem preferable, even unwanted direct limitation.

It would probably be easier to put a ceiling on use before it reaches too high a level than to cut it back afterwards. Therefore, in view of the rapid expected increase in visitors, the time to plan for the desired amounts of use and for methods to hold numbers to this level is soon.

This study has suggested tentatively the levels of satisfaction associated with different amounts of use, which any policy decision should consider; but it does not indicate which level of satisfaction should be the goal. No present data tell us if a "full wilderness" experience for 100,000 canoeists yields greater total satisfaction than a "half wilderness" experience for 200,000 canoeists. Perhaps research or some sort of poll of visitors would help. At present, the decision must be subjective.

One possible method of control might involve allowing unlimited use on the first and perhaps the second lakes, but requiring travel permits, issued in limited numbers each week for each access, for travel beyond. Charges for permits would be another possibility. The price might be graduated to encourage use in the off-season and at underused points. Charges could also discourage use by people who do not need or desire the special qualities of the area, if alternatives were provided for them.

Logging

The limited logging policy as now practiced seems to interfere with the wilderness experience of a fairly small proportion of the visitors. Use is light in the areas of extensive logging, however. The hypothesis that use is light because of logging cannot be rejected at present, although most users were unaware of any cutting and thus would not seem to be avoiding it consciously — similar southern areas without logging were also lightly used. The whole question merits further study.

Roads

The road controversy in the past has centered on a choice between good roads or bad roads. This seems to miss the point and, in the opinion of people interviewed, has led to the wrong choice. The real choice seems to lie between good, but low-speed, scenic roads, and the application of through-highway standards to dead-end wilderness approach roads. The study showed that no type of use (except possibly auto sightseeing) was reduced by either road miles from Duluth or miles of gravel road. The obvious choice, therefore, is scenic roads; these might be blacktopped, but need not be the shortest or most level routes possible. Perhaps inbound and outbound lanes could be separated to keep the roads narrow but safe. In

the outer two of the proposed zones, scenic side roads could be developed to deepen the auto sightseer's experience.

Campground Facilities

The desirability of locating future campgrounds in the outer zones has already been indicated. In addition, the people using campgrounds showed strong preferences for small, simple ones that provide privacy. Many people also showed an interest in hiking, an activity perhaps overlooked because of the overwhelming water orientation of the Quetico-Superior. More trails for hiking and better identification of existing trails might be desirable.

Canoe Campsites

The traditional simple facilities on the canoe trails seem to be preferred to "improvements" by most canoeists. Here again concentric zoning seems to offer possibilities for managing the area to accommodate diverse people. The people who dislike picnic tables (some intensely) are the ones who penetrate farthest; and conversely the groups that like them are concentrated in the fringe. Tables would seem undesirable after the first lake or two; and, even on the margins, some campsites could be left without tables.

Fireplaces are sometimes needed to encourage building fires in a safe location, but the simple ring of rocks, which any portage crew can build in a few minutes, seems to be liked better than the iron and cement structures, and it is much cheaper. Of course, people may move the rocks. On the other hand, if they do not like the fabricated concrete fireplace they will quickly build a ring of rocks anyway. The simple box pit toilet and garbage pit were never objected to in interviews.

Portages

Simple portages seem to be satisfactory. Docks could also be eliminated after the first few portages.

A FINAL COMMENT

An increasing number of Americans feel that outdoor recreation is an important part of a high standard of living. Social scientists in many disciplines are also beginning to take a greater interest in leisure behavior and, within this general interest, in outdoor recreation.

The approach used in the two Quetico-Superior studies was simple. The distribution of the use of the recreational resources of the Quetico-Superior area was described and analyzed, and an attempt was made to learn how the users viewed these resources. Much of the apparent dilemma of contradictory desires by diverse visitors disappeared when their ideas and their geographic distribution over the area were studied. This combination of distributional and perceptual study seems well suited to research in the ill-defined field of conservation, and it is particularly appropriate for consideration of recreational land use. It could lead to a more flexible view of wilderness resources and a higher return from wilderness everywhere. Maintaining flexibility is usually hard, but the alternative may be Leopold's "self-defeating wilderness preservation."

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OCTOBER 1964

SEDIMENT, STREAMFLOW, and LAND USE RELATIONSHIPS in NORTHERN LOWER MICHIGAN

W. David Striffler

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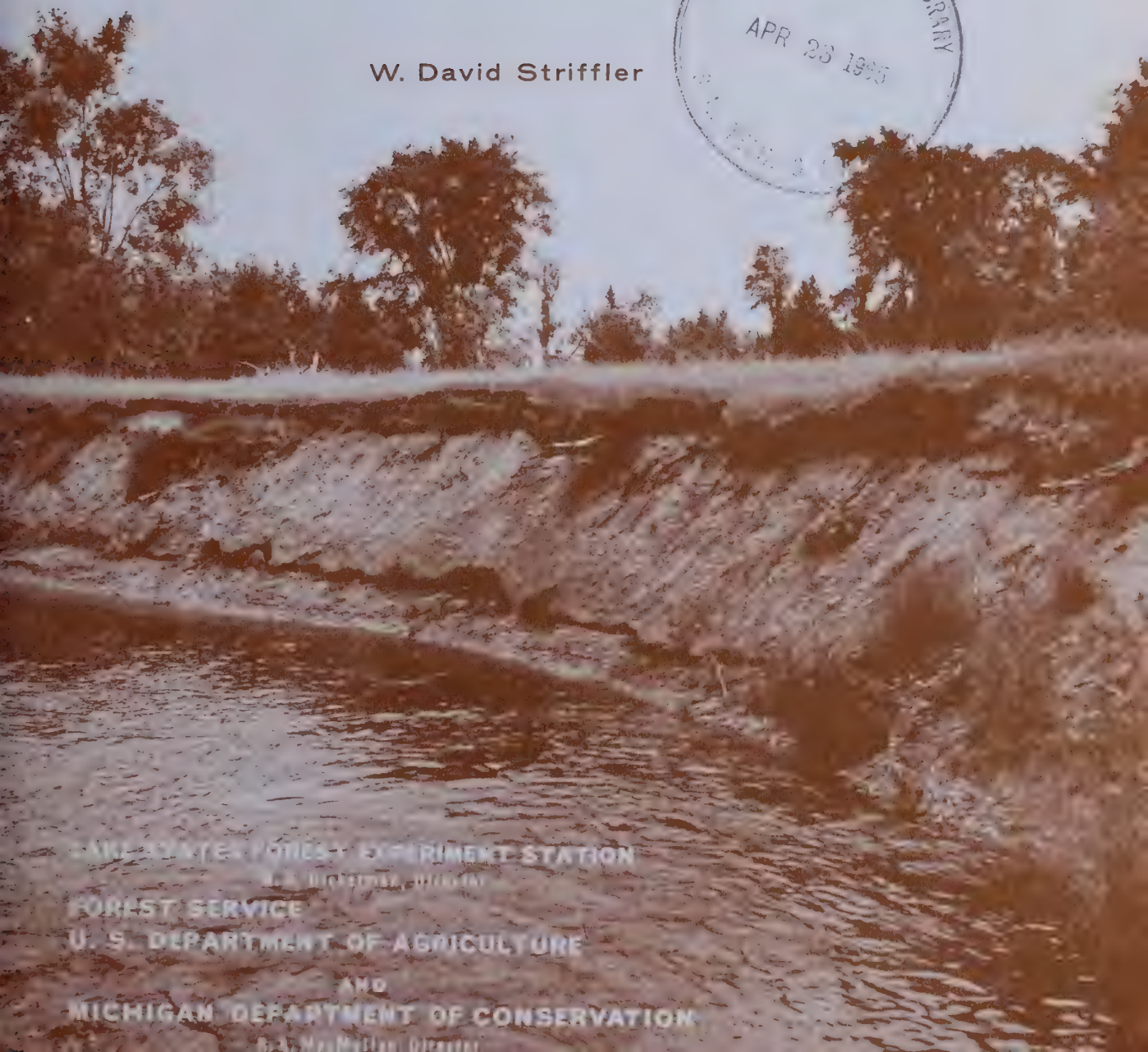

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Contents

Introduction 1

Review of Literature 1

The Area 2

Methods 5

Land Use and Streamflow 7

Land Use and Sediment Discharge 8

Eroding Banks 10

Summary and Conclusions 11

Literature Cited 12

Cover picture: A typical eroding bank, Tobacco River Watershed. Note scour line at the base of bank.

Introduction

Sediment in a stream can come from many sources and is influenced by many agencies. One of the most widely recognized influences is the way in which man uses the land. In general, the greater the disturbance to the watershed, the greater the effect upon streamflow and the greater the yield of sediment from the watershed. Many forms of disturbance have been recognized, including road construction, logging, agricultural practices, and grazing.

This paper reports the results of a study designed to evaluate the sediment contribution from the major land use types occurring within a typical mixed-use watershed in northern Lower Michigan.

Review of Literature

Stream sediment has been recognized as one of man's major land use problems since the days of the ancient Egyptians, Chinese, and Mesopotamians. The relationships between land use or abuse and the amount of sediment in the stream have been observed over the centuries. More than a hundred years ago, the effect of the removal of forest cover in particular was mentioned by Sir Charles Lyell (1849)[1]; on a trip to the United States he commented on the effect of forest clearing on the sediment loads. Ashe (1907) discussed the effect of forest clearing and soil type on sediment loads in the Potomac River and suggested that certain highly erodible soils within the watershed should not be cleared when slopes exceed a certain level.

During the conservation movement of the 1930's, runoff and erosion received considerable attention. A large share of the work concentrated on comparative erosion rates under various vegetative densities, cover crops, or other vegetative expressions (U.S. Dept. Agr. 1940). Relatively high erosion rates occur under open row crops (such as corn and cotton) while less erosion occurs from small grains, pasture, and hay land. Forest lands are generally recognized as having minimum soil losses.

Only recently, however, have modern statistical techniques made possible reasonable quantitative evaluations of watershed characteristics and conditions upon stream sediment yields.

Anderson (1949) found a close relationship between annual sediment accumulation in eight reservoirs and the maximum annual peak discharge, the area of the main channel, and the cover density on the watershed.

Anderson and Trobitz (1949) related peak discharge and sediment deposition resulting from a major flood to the area of barren land, maximum 24-hour precipitation, area of old fires, and an estimate of cover density. Twenty-five watersheds were analyzed.

In western Oregon, Anderson (1954) related the average annual sediment yield in 29 watersheds to 16 watershed factors. These included fixed factors such as area, channel gradient, soil erosibility, silt plus clay, and a surface aggregation ratio; hydrologic factors such as mean annual discharge and discharge

[1] *Names and dates in parentheses refer to Literature Cited at the back of the report.*

NOTE: At the time this study was made, the author was Leader of the Station's Ground Water Hydrology and Streambank Erosion Project at Cadillac, Mich. He has since been transferred to the U.S. Central States Forest Experiment Station. The study reported here was conducted in cooperation with the Michigan Department of Conservation. Acknowledgment is due the Michigan Water Resources Commission for assistance in preparing rating curves, and to Professor Robert Zahner, University of Michigan, for assistance in the programming and computer analysis of the data.

peakedness, an index of stream variability; and land use variables such as the portion of the watershed occupied by poor cover, poorly stocked forest, roads, recently cut-over forest, bare cultivation, other cultivation, and length of eroding banks. In this study, Anderson attributes the sediment yield from the Willamette Basin as being derived as follows: 54 percent from eroding banks, 24 percent from 5,460 square miles of forest land, and 22 percent from 1,820 square miles of agricultural land.

The Area

This study was conducted within the Tobacco River Basin in Michigan's Lower Peninsula (fig. 1). The Tobacco was selected for several reasons. First, the basin encompasses a part of both the northern forested region and the southern agricultural region of the State. Thus, within the basin occur broad areas representative of the major land use categories of Michigan. Second, the Tobacco River is composed of sufficient branches and tributaries so that a number of small sample watersheds could be selected for each land use type. And finally, eroding banks (one of the variables to be evaluated in the study) had become a serious problem in a number of the sample watersheds.

The watershed occupies an area of 276 square miles. The river has three main branches plus many smaller tributaries totaling about 207 miles of permanent channel. The upper portion of the watershed is forested. Streams originating here flow through

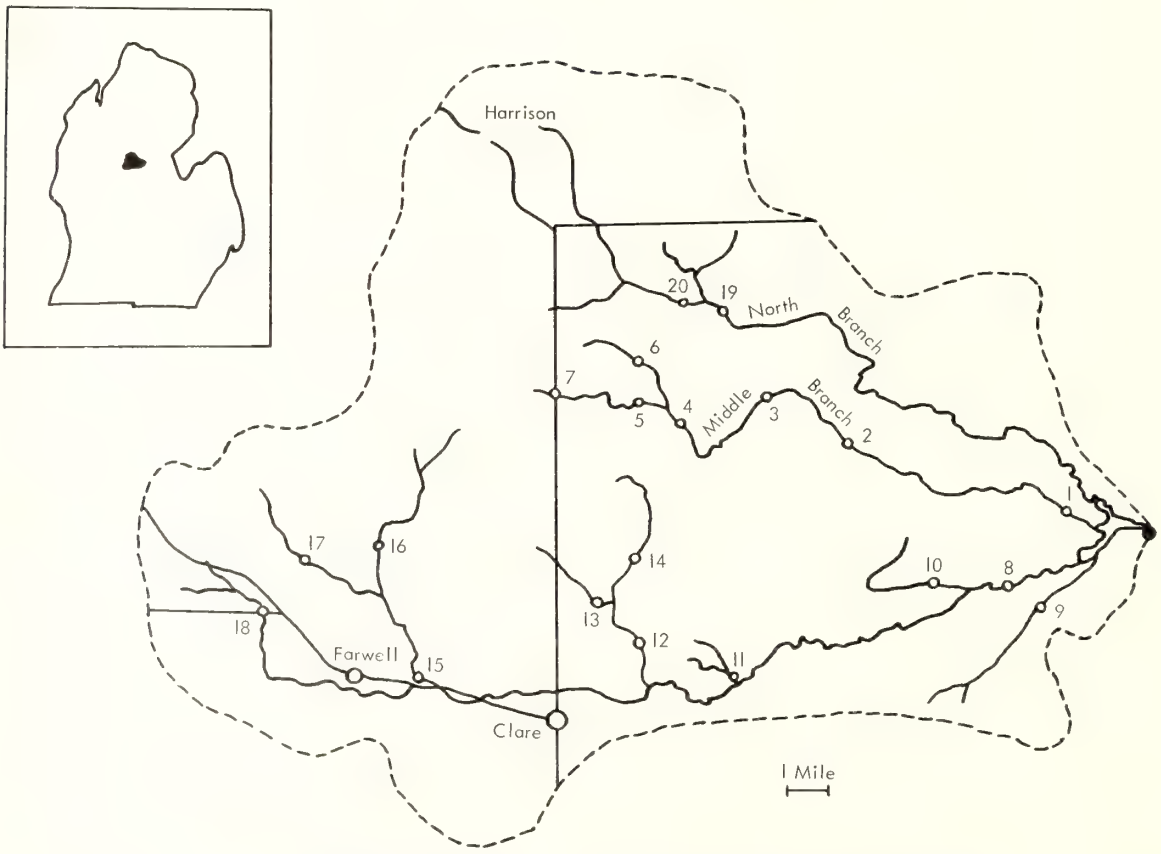

FIGURE 1. — Sampling stations within the Tobacco River Watershed.

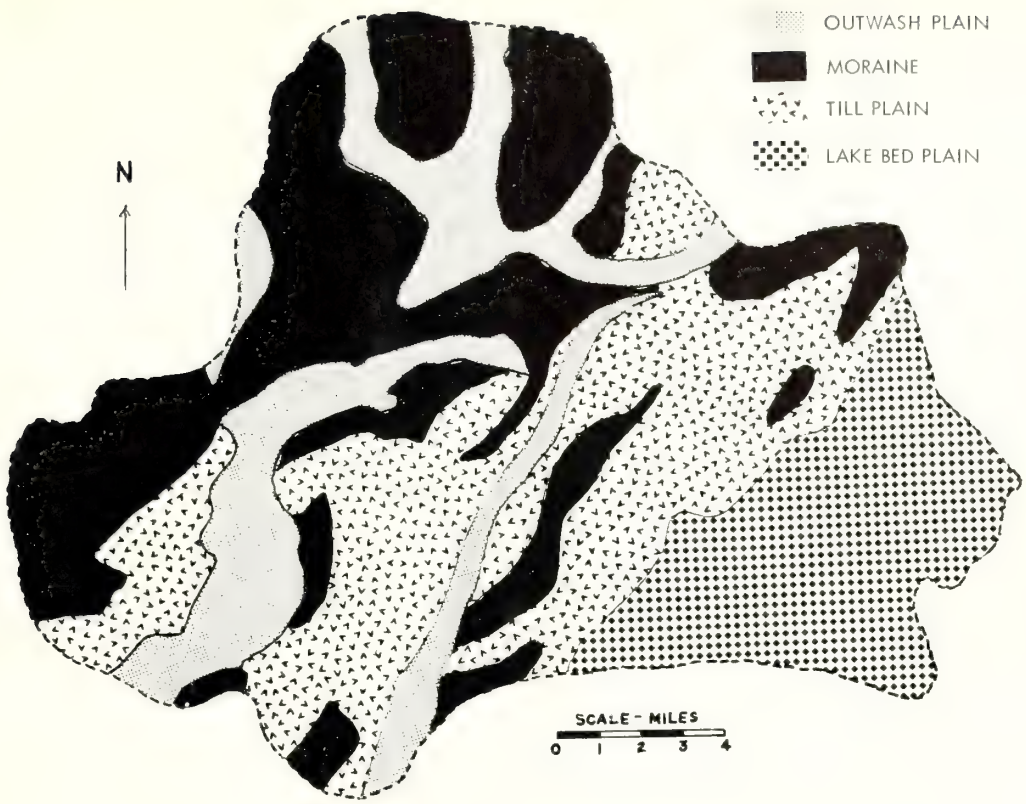

FIGURE 2. — Surface geology features, Tobacco River Watershed (after Martin 1955).

the agricultural lower watershed and finally empty into a reservoir at Beaverton. The headwaters portion of the three main branches has been classified as trout waters, while the lower portion is considered marginal in this respect.

The entire watershed is covered by a deep mantle of glacial drift (fig. 2). Four major types of surface deposits are commonly recognized. They include moraine, outwash plain, till plain, and glacial lake bed plain. The main streams flow successively through each of these types from west to east.

Within the morainal headwaters on the west the landscape is hilly to rolling, soils are sands or sandy loams, and streams are small and widely separated and exhibit uniform flow. Intermingled outwash plains consist of ancient glacial drainage channels where soils are largely stratified sands and gravels. Such deposits are generally level and form channels for present-day streams.

The till plain deposits occur within the central portion of the watershed. They vary from level to rolling and are composed of heavy clay and clay loam soils. Streams are more finely branched than in moraine or outwash areas and exhibit a wide range of flows during the year.

Lake bed plains occur in the eastern end of the watershed. These are broad, level plains with sandy surface soils underlain by lacustrine clays at varying depths. Surface drainage is almost nonexistent except for artificial drains and the main branches of the Tobacco crossing the plain.

Land use within the basin is closely related to the surface geology and soils. Moraines with deep sandy profiles and sandy surface soils are largely forested (fig. 3). Till plains are largely agricultural, with use divided between cultivated lands and pasture lands (fig. 4). Outwash plains are predominantly forested although they may be pas-

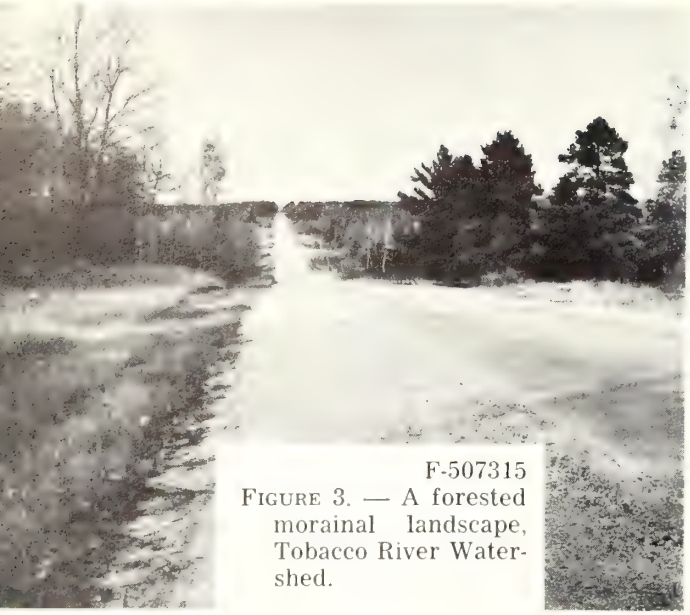

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FIGURE 3. — A forested morainal landscape, Tobacco River Watershed.

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FIGURE 4. — A typical cultivated till plain landscape.

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FIGURE 5. — Deep sandy outwash plain devoted to pasture and forest.

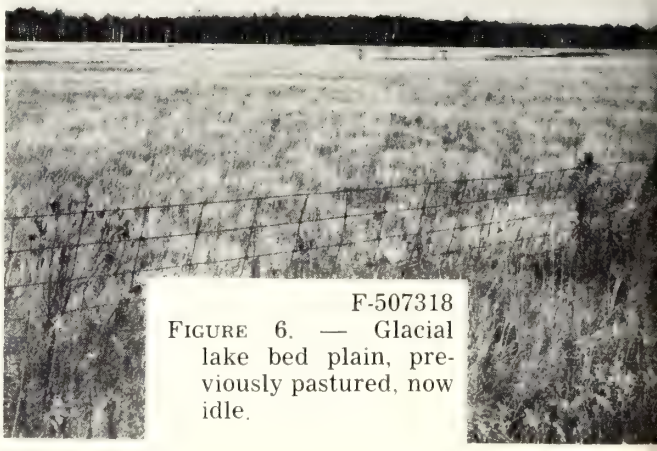

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FIGURE 6. — Glacial lake bed plain, previously pastured, now idle.

tured when they occur adjacent to till plain soils (fig. 5). The use of the lake plains depends upon the depth of the sand mantle and the drainage within a particular area. Where the clay beds come to the surface the land is cultivated, but where the sand mantle is deep or surface soils are wet, forest and pasture lands predominate (fig. 6).

Methods

In general, two areas can be identified as sources of sediment: eroding streambanks and upland erosion. Since upland erosion varies according to land use, a more detailed classification of sediment source areas is necessary. For this study, upland erosion areas were classified into major land use categories including cultivated land, pasture land, wild land, and forest land.

A secondary objective of this study was to relate streamflow variables to the same land use variables being considered as sediment source areas. Since erosion and runoff are closely related, a relationship between land use and the range of observed streamflows could help explain why erosion from certain land use types was greater than others.

An ideal method of explaining these relationships would be to select individual sample watersheds from within each of the major land use types. Unfortunately, small sample watersheds occupied by single-use types are the exception, while mixed-use watersheds of various sizes and shapes are the rule. To determine the sediment contribution from each land use type within a mixed-use watershed and how sediment varies with different proportions of each land use, a multiple regression analysis using observations from a number of mixed-use watersheds was selected as the best approach.

Twenty sample watersheds were selected, each representing different conditions with respect to size, land use, and other watershed characteristics. A staff gauge was installed on each stream, and a curve relating stream stage to discharge was prepared for each sample watershed. Sediment samples and stream discharge measurements were taken at irregular intervals between September 1960 and April 1962. Hydrologic events occurring included two snowmelt periods and several heavy rainstorms. During the study 840 sediment samples were collected, about half of them during snowmelt or stormflow periods. Instruments used were the US DH-48, US DH-59, and automatic single-stage sediment samplers. Each time a sample was collected, the stream stage was recorded and also whether the stream was rising or falling.

Sediment samples were analyzed by evaporating the moisture and weighing the residue. Organic components were first removed by oxidizing with hydrogen peroxide (H_2O_2). A correction for dissolved solids was also required. Sediment discharge rates were computed by multiplying the weight of the sediment per unit of water times the stream's discharge.

Land used for each of the sample watersheds was classified by means of aerial photographs and a field survey. Land use categories were defined as follows:

Cultivated land.—Included all land planted to an annual crop during the summer of 1961. Primary crops in the Tobacco River Watershed include corn, wheat, oats, other small grain, and a small percentage of row crops other than corn. It was assumed that these represented the total land area in the watershed that was plowed at least once a year.

Pasture land. — Included cattle pasture, sheep pasture, and a small amount of horse pasture. Hay lands were also included in this category since cutover hay lands are frequently pastured and generally have a continuous cover for 2 or 3 consecutive years.

Wild lands. — Included brush lands, nonforested bogs or swamps, abandoned land, and other idle lands. These lands were usually well vegetated by grass or other low vegetation and had little erosion potential.

Forest land. — Included all forest land, farm woodlots as well as broad forested areas. Forests were predominantly northern hardwood and oak-aspen with small areas of lowland hardwoods, swamp conifers, and coniferous plantations.

The multiple regression analysis was computed on the University of Michigan IBM 709/7090 computer, using a standard program known as the Westervelt Modified General Motors Multiple Regression Program. This is a stepwise analysis which selects and analyzes those variables most closely related to the independent variable. A multiple regression coefficient, coefficient of determination, and "F" level were computed for each variable entering the analysis. In this manner, only the most important variables were included in the analysis while variables entering the analysis at non-significant "F" levels were dropped. The significant variables in the study include stream discharge, rising or falling stage, eroding banks, and the individual land use variables. A separate equation was developed for each individual land use variable rather than for all variables grouped together.

Watershed characteristics are summarized in table 1.

TABLE 1. — *Summary of watershed characteristics for sample watersheds*

Station	Area	Eroding banks	Area in land use			
			Cultivated	Pasture	Wild land	Forest land
	Sq. miles	*100 ft.*	*Percent*	*Percent*	*Percent*	*Percent*
1	36.6	38	11	26	28	34
2	27.4	28	10	26	28	34
3	22.8	15	7	23	32	37
4	15.2	0	3	12	36	48
5	8.3	0	4	11	37	47
6	4.7	0	1	3	37	57
7	1.0	0	0	0	35	65
8	134.3	62	13	23	26	35
9	8.1	0	7	18	30	44
10	2.3	0	22	28	24	24
11	3.4	10	45	37	6	9
12	16.3	20	23	38	22	14
13	4.8	0	22	42	16	18
14	5.8	0	26	33	22	17
15	28.6	1	2	8	26	62
16	20.6	0	1	5	25	68
17	3.7	0	0	2	30	67
18	5.1	0	3	19	23	50
19	48.1	27	2	8	18	68
20	38.9	0	2	6	19	67

Land Use and Streamflow

Streamflow regimens are well known to be regulated by land use, soils, and other factors. In general, watersheds with fine-textured or shallow soils or cultivated lands have highly variable streams — that is, they exhibit low summer flows and high stormflow peaks. On the other hand, forest lands or watersheds with deep, coarse-textured soils generally exhibit higher summer flows and lower stormflows. These relationships were observed in this study.

Continuous streamflow records were not collected. Streamflow data consist of about 40 individual observations for each watershed, about half of which were taken during snowmelt or stormflow recession (table 2). Therefore, mean daily discharge values or frequency data cannot be extracted.

The range of observed discharge, however, very closely approaches the actual annual range of discharge. In the analysis, the range of observed discharge rates was used as an index of stream variability and was related to land use (fig. 7).

As shown in figure 7, the range (the difference between maximum and minimum flow) in stream discharges occurring within a watershed varies according to the proportion of the watershed occupied by the various land use types. Maximum discharge rates tend to increase as the area of cultivated and pasture land increases. Theoretically, a water-

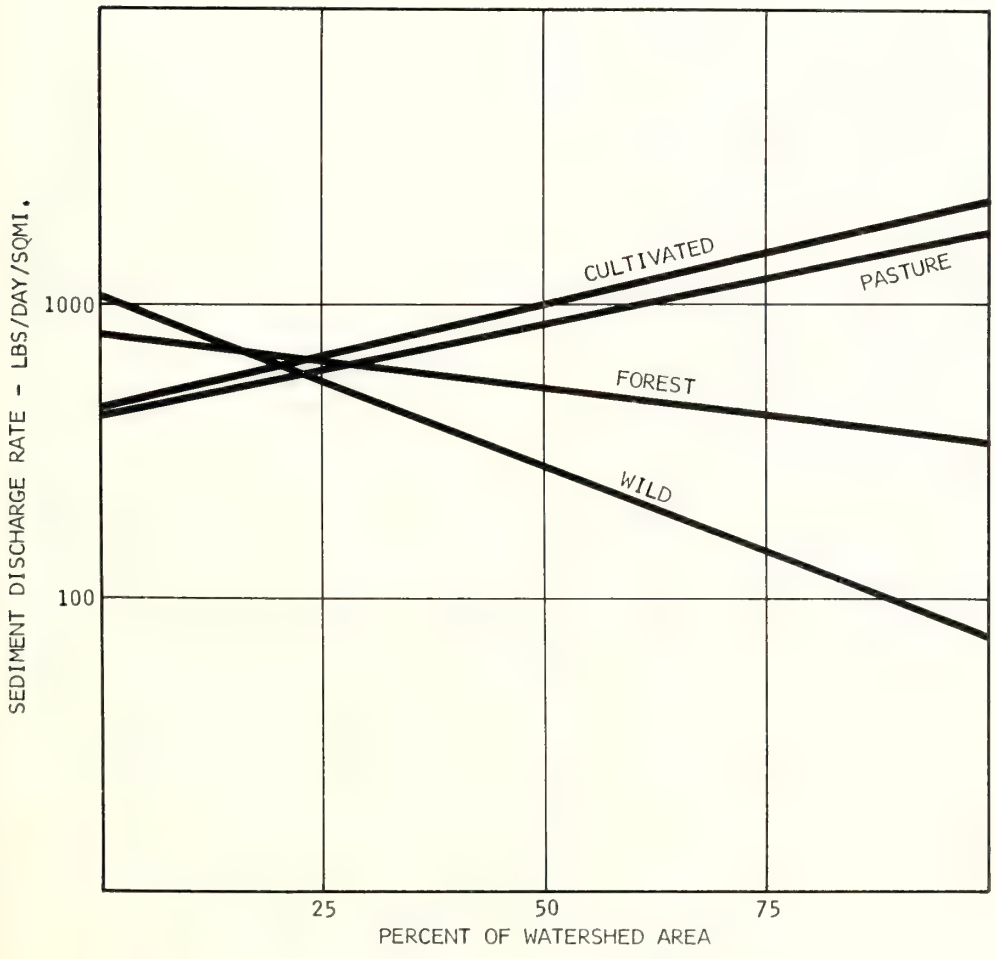

FIGURE 7. — Relationship between stream sedim discharge variability and land use.

TABLE 2. — *Observed discharge rates, September 1960 through April 1962*
(Cfs/sqmi.)

Station	Minimum	Maximum	Range	Mean
1	.505	5.500	4.995	1.455
2	.620	6.200	5.580	2.123
3	.613	6.132	5.519	2.084
4	.792	10.759	9.967	2.425
5	.993	3.717	2.724	2.200
6	.479	1.809	1.330	.904
7	2.900	10.000	7.100	5.754
8	.261	6.128	5.867	1.295
9	.001	5.700	5.699	.333
10	.022	12.320	12.298	2.277
11	.059	13.166	13.107	1.712
12	.154	5.682	5.528	1.185
13	.208	8.340	8.132	2.541
14	.017	4.862	4.845	.752
15	.454	3.195	2.741	1.261
16	.461	3.783	3.322	1.285
17	.137	1.616	1.479	.719
18	.119	4.198	4.079	1.057
19	.436	3.117	2.681	1.179
20	.459	5.736	5.277	1.316

shed entirely cultivated could have a spread in discharge rates of 85 cubic feet per second per square mile (cfs/sqmi.), while a watershed entirely pastured could have a range in discharge rates of about 50 cfs/sqmi. On the other hand, a completely forested watershed would theoretically have a difference of about 1.6 cfs/sqmi. between maximum and minimum flow, while a wild land watershed would have practically no variation at all (.13 cfs/sqmi.). Since watersheds of this nature (single land use type) are rare, the values quoted are entirely hypothetical. However, in the range of existing land use proportions, the observed ranges of flow fit the curves quite well.

Land Use and Sediment Discharge

The suspended sediment load in a stream at any one time is the result of two interrelated processes. These are (1) the erosion process involving the actual detachment of the soil particles, and (2) the transportation of the sediment particles. Both of these processes affect the amount of sediment in the stream. For example, a short intense summer storm may cause considerable erosion in a field but, if there is not enough runoff to carry the soil material into the stream, it will be redeposited downslope and stream sediment concentration may not be greatly affected. On the other hand, if large volumes of water become available (such as occurs during a snowmelt period) the transporting ability of the runoff will be great compared to the amount of sediment removed and sediment concentrations will remain lower than normal for the volume of runoff. The more common situation would be for both streamflow and sediment discharge to increase simultaneously.

An earlier analysis (Striffler 1963) indicated that sediment concentration in the Tobacco River is related to stream discharge and to whether the stream is rising or falling. Since these two variables explain a considerable portion of the total observed variation (31 percent) without obscuring land use effects, they were included in the analysis (fig. 8).

The multiple regression equations derived thus include two streamflow variables (stream discharge = Q, and rising and falling stage = R/F), the length of eroding banks (EB), and individual land use variables.

(1) $\log \text{Sed}_Q = 3.100 + 1.288 \log Q - .573\ R/F + .182 \log EB + .007$ cultivation ($R = .84$)

(2) $\log \text{Sed}_Q = 3.059 + 1.286 \log Q - .568\ R/F + .168 \log EB + .007$ pasture ($R = .84$)

(3) $\log \text{Sed}_Q = 3.482 + 1.289 \log Q - .584\ R/F + .189 \log EB - .012$ wild ($R = .84$)

(4) $\log \text{Sed}_Q = 3.329 + 1.281 \log Q - .569\ R/F + .179 \log EB - .004$ forest ($R = .84$)

The relationships between sediment discharge rates and land use are illustrated in figure 9. Sediment discharge rates increase with increasing proportions of cultivated and pasture land and decrease with increasing proportions of forest and wild land. Cultivated land yields slightly more sediment than pasture land, all other conditions being equal. For example, a watershed completely cultivated would have an average sediment yield rate of 2,200 lbs/day/sqmi. while a pastured watershed would yield 1,800 lbs/day/sqmi. (fig. 10). An earlier analysis of the data indicated that pasture land had a greater sediment yield rate than cultivated land (Striffler 1963). However, by placing the individual land use variables into separate equations, the reverse becomes clear.

Forest and wild land yield sediment at substantially lower rates than either cultivated or pasture land. Forest land had an

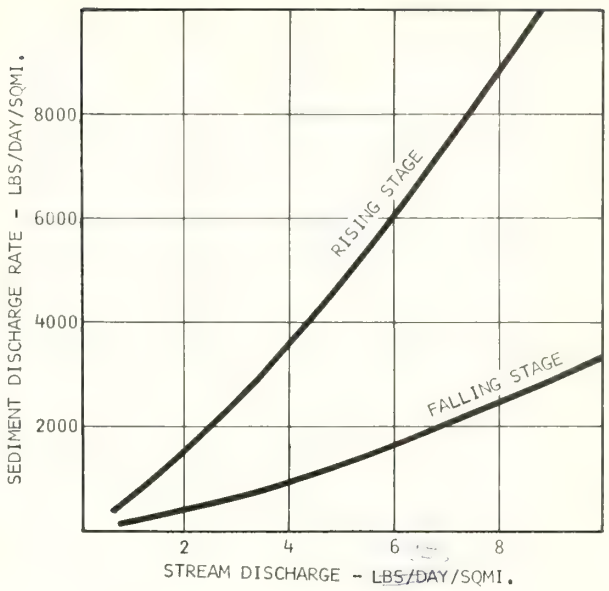

FIGURE 8. — Relationship between stream discharge and sediment discharge rate.

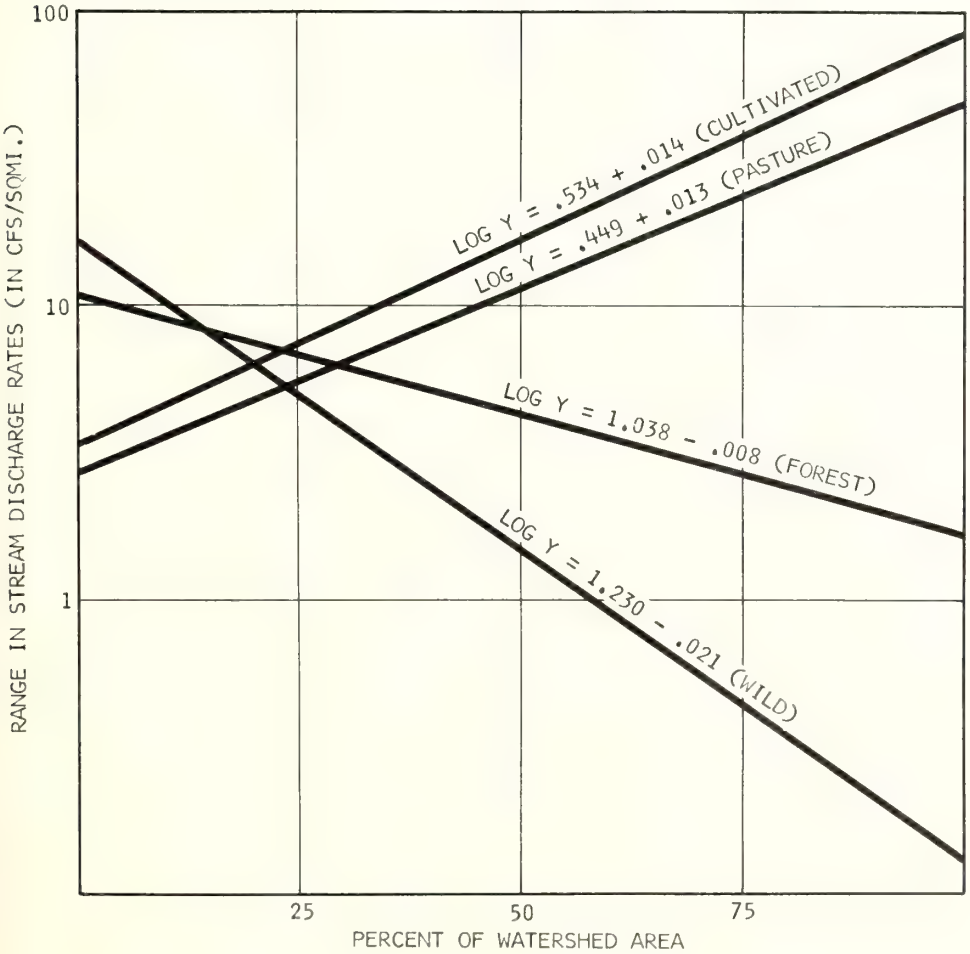

FIGURE 9.—Relationship between sediment discharge rates and land use.

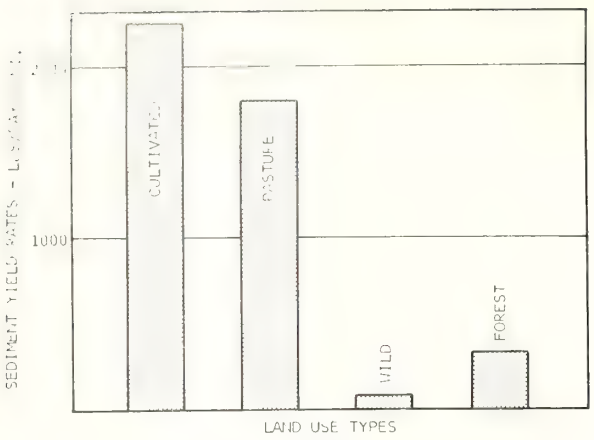

FIGURE 10. — Average sediment discharge rate by land use types.

average sediment yield rate of 360 lbs/day/sqmi., while wild land had an average sediment yield rate of about 74 lbs/day/sqmi. (fig. 10). The lower yield rate from wild land is probably because of the large areas of bogs and brush-covered swamps (areas which would have almost no erosion) whereas forest land included sloping land and a number of farm woodlots on heavy soils, which would produce more sediment.

In the Tobacco River Watershed, the average sediment load can be attributed to the various sources as follows:

	Percent
Eroding banks	33
Cultivated land (10 percent of area)	15
Pasture land (18 percent of area)	24
Wild land (26 percent of area)	5
Forest land (44 percent of area)	23

Land use in northern Lower Michigan is closely related to the soils and geology. Because of this close relationship, the results of this study as expressed in the equations must be used with caution. The land use variables as used and discussed do not yield a simple sediment land use relationship but rather an integrated relationship with land use and its associated soils or geologic features. The equations derived express the average situation as it now occurs and cannot be used to predict the effects of a land use change.

Eroding Banks

Eroding banks within the watershed are an important source of suspended sediment. In the 20 sample watersheds, an average of 33 percent of the measured suspended sediment load is attributed to eroding banks (see cover picture). This proportion varies among the sample watersheds according to the length of eroding bank (fig. 11).

The importance of eroding banks as a sediment source suggests that suspended sediment loads might be substantially reduced through bank stabilization treatments. Of the seven sample watersheds with important bank erosion problems, estimated potential sediment reductions range from 54 to 35 percent (table 3). Whether such reduction can actually be attained remains to be tested.

TABLE 3. — *Predicted sediment reductions by stabilizing eroding banks*

Sample watershed	Eroding banks	Average sediment	Predicted sediment	Potential reduction
	100 ft.	*Lbs/day/sqmi.*	*Lbs/day/sqmi.*	*Percent*
1	38	690	360	48
2	28	640	350	45
3	15	550	330	40
8	62	780	360	54
11	10	960	620	35
12	20	750	430	43
19	27	560	310	45

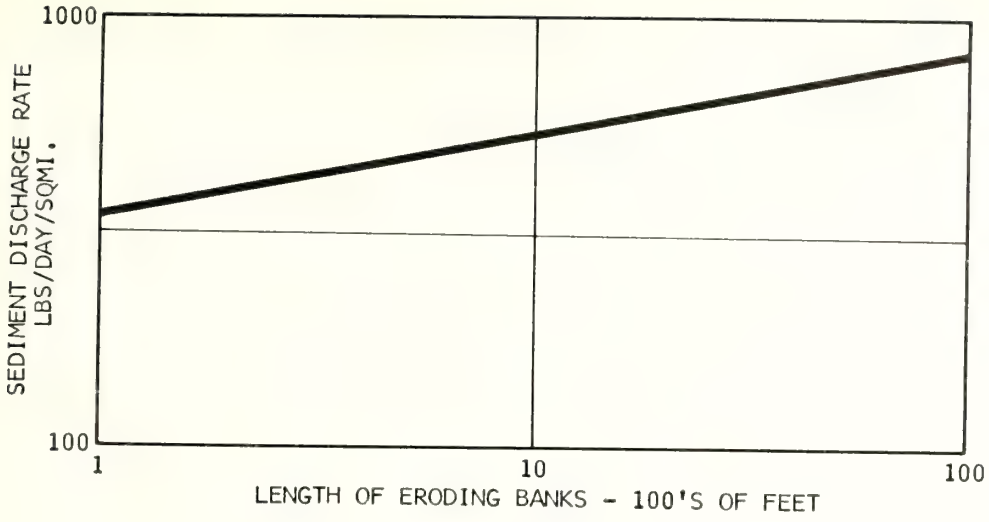

FIGURE 11. — Relationship between length of eroding banks and sediment discharge rate.

Summary and Conclusions

In the Tobacco River of northern Lower Michigan, both streamflow variability and sediment discharge rates are related to land use. These relationships are due partly to the land use factor and partly to the soil types generally associated with specific land use categories. Cultivated and pasture lands, which receive annual disturbance in the form of plowing or grazing and which are largely confined to finer textured till plain soils, demonstrate extreme variability in both stream discharge rates and sediment discharge rates. On the other hand, forest and wild lands, which are comparatively undisturbed and which are generally associated with coarse-textured soils, have unusually stable stream discharge rates and are relatively low sediment contributors.

These relationships were determined for the Tobacco River Watershed by means of a multiple regression analysis of sediment and streamflow observations taken from 20 sample watersheds each representing varying conditions with respect to land use and degree of bank erosion. Results may be summarized as follows:

1. Cultivated land occupying 10 percent of the watershed and with an average sediment yield rate of 2,200 lbs/day/sqmi. contributed 15 percent of the average observed suspended sediment load. The range of stream discharge rates could theoretically show a spread of 85 cfs/sqmi. from a completely cultivated watershed.

2. Pasture land occupied 18 percent of the watershed and had an average sediment yield rate of 1,800 lbs/day/sqmi. Twenty-four percent of the average sediment load was attributed to pasture land. The range in stream discharge rates from a completely pastured watershed could theoretically differ by 50 cfs/sqmi.

3. Wild land was the lowest sediment contributor of all land use types, contributing about 5 percent from 26 percent of the area. The average sediment yield rate was 74 lbs/day/sqmi. Streamflow observations from wild land watersheds would theoretically vary less than 1 cfs/sqmi. The low sediment yield rate and unusually stable flows are probably due to the large areas of nonforested swamps and bogs included in the wild land classification.

4. Forest land was also a low sediment producer, contributing 23 percent of the average sediment load from 44 percent of the area. The average sediment yield rate from a forested watershed would be about 360 lbs/day/sqmi., while streamflow would have an annual variation of about 1.6 cfs/sqmi.

5. Eroding banks are an important sediment source. In this study, about one-third of the average suspended sediment load is attributed to eroding banks. The importance of eroding banks suggests that substantial sediment reductions could be achieved through bank stabilization.

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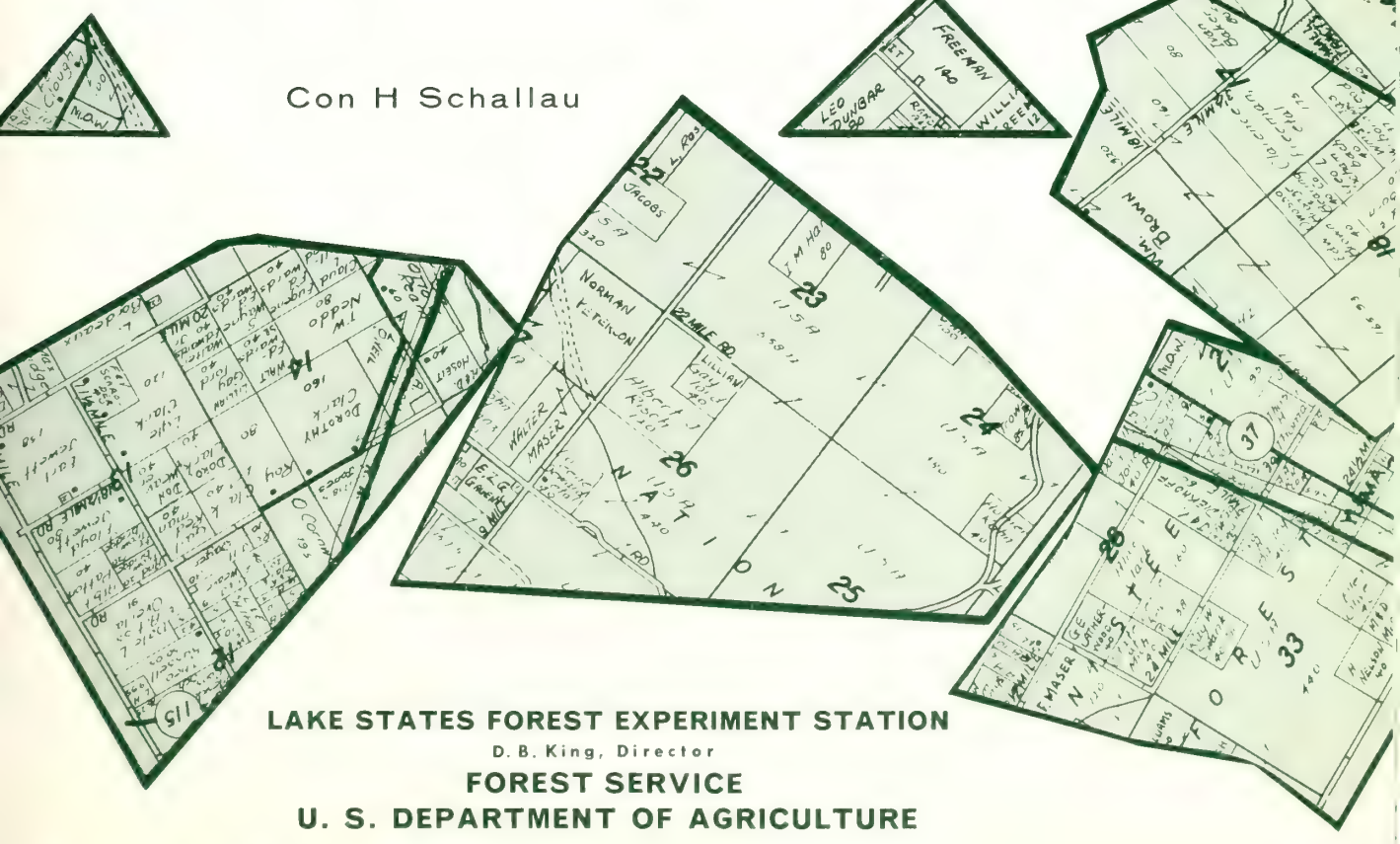
FRAGMENTATION, ABSENTEE OWNERSHIP, *and* TURNOVER *of* FOREST LAND *in Northern Lower Michigan*

Con H Schallau



LAKE STATES FOREST EXPERIMENT STATION
D. B. King, Director
FOREST SERVICE
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CONTENTS

Page

The Problem 1

Study Highlights 1

Private Ownership Predominates in Study Area 2

334 Sample Sections Allocated to 16 Counties 2

Area Within and Contiguous to Sample Sections Used to Measure Changes in Tract Size 2

Trend Was Toward More Properties 4

Breakup of Large Forest Ownerships Reduced Average Size 5

Change in Block Size Not Related to Farming or Nearness to Cities .. 5

Subdivision for Summer Homesites Not Too Important 7

Fragmentation Likely to Continue 8

Absentee Ownership Likely a Determinant of Timber Availability .. 9

Property Rights in Forest Land in Continual State of Flux 10

Discussion and Conclusions 11

Appendix: Sampling Accuracy 12

The Problem

During the summer of 1962 I spent several weeks checking county tax records and plat books to determine the acreage of large ownerships (i.e., those of more than 5,000 acres) in Michigan. I found that a number of large ownerships, still in existence as late as 1954, had since been divided and sold.[1] These findings prompted the question, "Are Michigan's forest properties in general getting smaller?" On the other hand, consolidation of smaller properties might have compensated for the breakup of large properties.

Why be concerned about the size of forest properties? We'll explore the reasons a little later but one point of concern is that, theoretically, reducing the average size of tract would decrease the economic supply of timber, other things remaining constant. Of course, the reverse would be true if the size of forest properties increased.

Although the harvest of Michigan's timber can undoubtedly be increased, there's the question, "How much?" Until we have economic supply data we can only use the Forest Survey figures on physical supply. This study examines certain ownership changes and is part of an effort to estimate economic supply.

Study Highlights

Privately owned forest properties in the northern 31 counties of Lower Michigan are getting smaller. The average size of contiguous forest tracts in 1946 was 182 acres; in 1962 the average had dropped to 156 acres.[2] The breakup of large forest ownerships caused most of the reduction. In 1946 the average acreage of forest land within and contiguous to the sample sections chosen in this study was 979 acres. By 1962 it had dropped to 860 acres — a decrease of 119 acres. The reduction in large forest ownership acreage accounted for 64 percent of this difference, with medium and small properties accounting for the rest.

Most postwar fragmentation of forest land took place between 1946 and 1954. Several large ownerships were being divided during this period. Although fragmentation has been more gradual since, it is likely to continue.

Acreage of absentee ownership increased by 45 percent during the 1946-1962 period. Unlike fragmentation, most of which occurred shortly after World War II, absentee ownership continues to increase at a fairly steady rate. Also, absentee ownership increased uniformly throughout the study area, whereas fragmentation was more prevalent in the more heavily forested counties.

The high turnover of forest properties since World War II is apparent. Only 40 percent of the forest area had just one owner since 1946; 44 percent of the area had two owners, while 16 percent had three owners.

Forest survey data indicate that Michigan's physical supply of timber is increasing. But the increase in physical supply doesn't necessarily mean that more timber will be marketed. To accomplish the latter, owners must be willing to sell more timber at prices that buyers are willing to pay. Both buyer and seller decisions are bound to be affected by the ownership changes identified in this study.

Very likely, fragmentation and property turnover restrict the economic supply[3] of timber while absentee ownership could increase as well as decrease it. Further studies will be needed to show in what direction and how much supply is affected by these factors.

---

[1] *Con H Schallau. Forest owners and timber management in Michigan, U.S. Forest Serv. Res. paper LS-9, 39 pp., illus. 1964 (See p. 20) Lake States Forest Expt. Sta., St. Paul, Minn.*

[2] *Definitions of "contiguous forest tract," "sample section," and "sizes of ownership" appear on pages 2 and 3.*

[3] *The physical supply of timber is the total volume in existence. Economic supply is a schedule showing quantities that would be marketed at various prices.*

Note: The author is an Economist on the staff of the Lake States Forest Experiment Station, which is maintained at St. Paul, Minn., by the Forest Service, U.S. Department of Agriculture, in cooperation with the University of Minnesota. *Appreciation is expressed to personnel of county treasurer offices for their patience and assistance and to the U.S. Agricultural Stabilization and Conservation Service in Lansing, Mich., for the use of their aerial photos.*

Private Ownership Predominates in Study Area

The area chosen for this study is the 31 northernmost counties of Lower Michigan (fig. 1). This area's 7.5 million acres of commercial forest cover 71 percent of its land surface. About two-thirds of the forest area is privately owned.

Pulpwood is rapidly becoming the mainstay of the study area's timber-using industry. Currently it accounts for slightly more than 50 percent of the total timber harvest. Output of pulpwood has shown a rapid increase during the past decade. In 1963, for instance, 494,000 cords of pulpwood were harvested, or about 126 percent above the 1954 level. This upward trend should continue. The fact that the timber base could support a higher cut is an encouragement for present mills to increase capacity and an attraction for new industries.

Northern Lower Michigan is sparsely populated. The 1960 Census showed only 5 percent of the State's 7.8 million people residing there. But its forests and lakes make it a vacationland for many Michigan and out-of-state residents.

334 Sample Sections Allocated to 16 Counties

To reduce travel time, the study was conducted in only 16 of the 31 counties of northern Michigan. These were randomly selected. Further, only half the townships in each county were sampled, here again for travel reasons. The basic sampling unit within each township was a 640-acre section; 334 sections, or approximately 2 percent of the study area's total acreage, were allocated among the counties in proportion to their land areas.

For analytical purposes the 16 counties were stratified into 5 zones according to forest density (see fig. 1 for location of counties):

Zone	*County*	*Percent forested*	*Number of sample sections*
1	Oceana, Osceola	40-55	41
2	Gladwin, Mason, Midland	56-65	55
3	Alpena, Charlevoix, Clare, Missaukee, Newaygo, Wexford	66-75	124
4	Cheboygan, Presque Isle	76-85	48
5	Alcona, Lake, Montmorency	86 plus	66
All zones		71	334

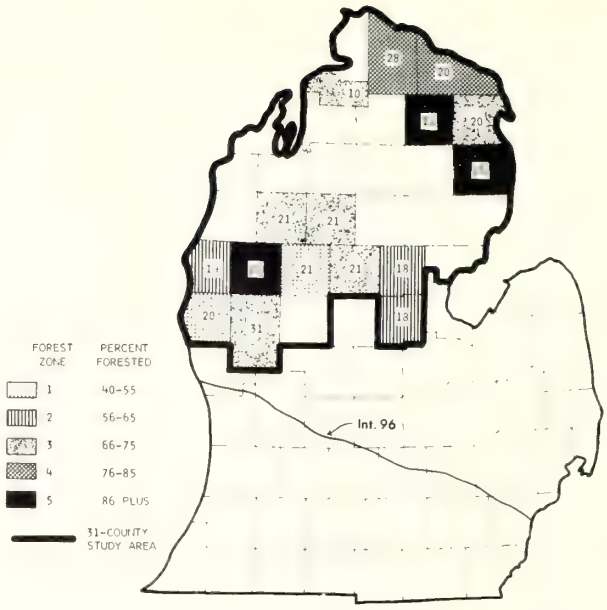


FIGURE 1. — Sixteen sample counties were selected randomly within the study area. A total of 334 sample sections, representing about 2 percent of the land area in the 31 counties were allocated in proportion to the land areas of the counties. The numbers indicate how many sample sections were allocated to each county.

Area Within and Contiguous To Sample Sections Used to Measure Changes in Tract Size

Change in size of forest tracts can be measured in several ways. Trends in large ownership acreage is one way but such trends provide only partial checks. Change could also be measured by counting the number of properties at various points in time. But as shown in figure 2, number of properties alone could lead to false conclusions. One might conclude that only fragmentation had occurred in instances where consolidation was just as important.

I tabulated the number of forested properties at three points in time: 1946, 1954, and 1962 (see figure 3 for technique used). I also measured forest area in each sample section, and *in addition*, forest land "contiguous to" the sample section and owned by individuals having property in the sample section. My objective in this phase of the study was to measure the breakup and the consolidation of forest properties, and this sampling scheme allows for the fact that individual properties

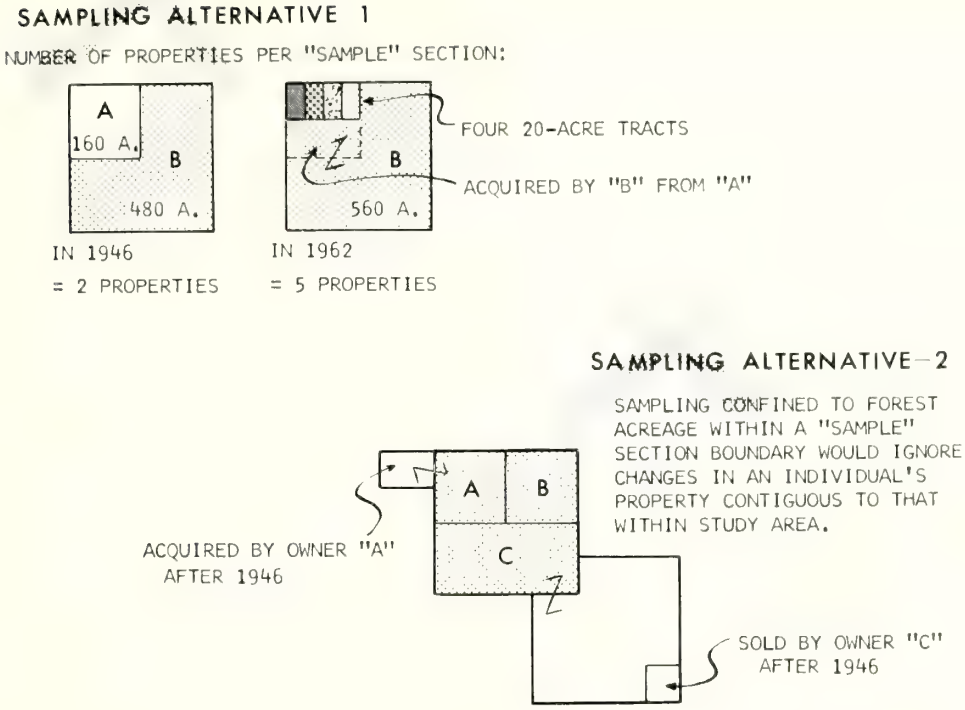


FIGURE 2. — Breakup or consolidation of forest properties cannot be measured by merely counting the number of properties in a sample (alternative 1). Such a technique could conceivably suggest sizable changes toward fragmentation when, in effect, consolidation might be as great or greater. One improvement is to measure forest area as well as the number of tracts (alternative 2), but even here the results might be misleading unless entire ownerships are considered. Alternative 3 does this and, therefore, allows for properties that overlap section lines.

frequently overlap section lines.

For easy reference I will be using the terms contiguous forest "block," and contiguous forest "tract"; a block is merely an aggregation of tracts. As figure 4 shows, both the forest tract and forest block can include area outside, but adjacent to, a sample section. If an individual has only a single stand of timber, then the size of his contiguous forest tract is the same as "total forest area owned." However, for individuals having other scattered tracts of timber not adjacent to the sample section, this is not true.

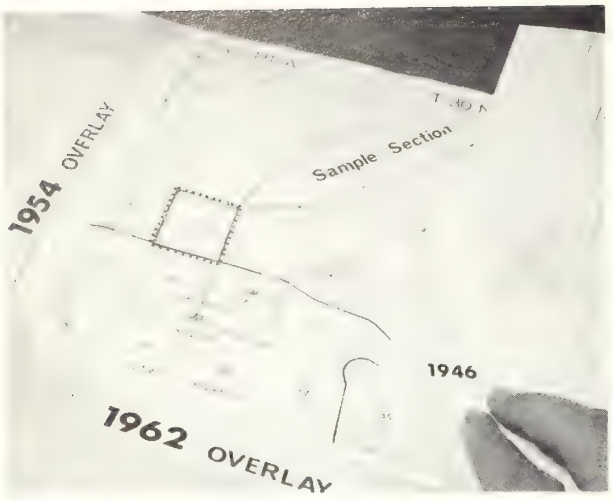


FIGURE 3. — County plat books provided base maps for this study. Tax rolls were checked for the years 1946, 1954, and 1962. Three vellum overlays, one for each year, were attached to a base map. Differences in parcel size and property owner between the plat book and tax rolls were sketched on the overlays. Owner's place of residence was also indicated. Forest acreages for contiguous tracts were determined from aerial photos and noted on base maps. Then, all of this information was coded on sample section summary sheets.

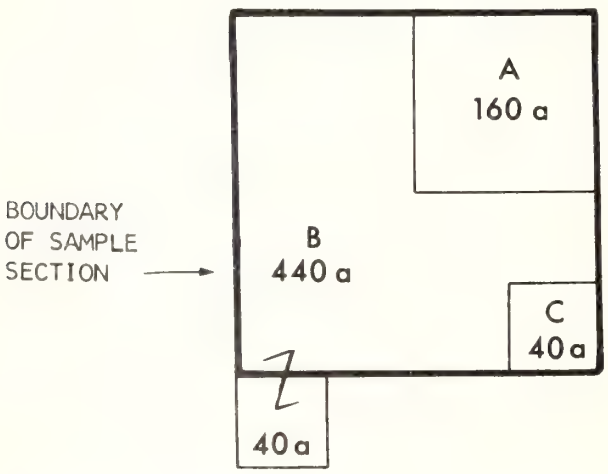


FIGURE 4. — The size of this contiguous forest block is 680 acres, of which 640 acres are within and 40 acres are contiguous to the sample section. This forest block is composed of three contiguous forest tracts: A, 160 acres; B, 480 acres; and C, 40 acres.

Trend Was Toward More Properties

Despite some consolidation, the trend during the 16-year study period was toward more rather than fewer properties. Table 1 shows that the size of contiguous forest blocks dropped from an average of 979 acres in 1946 to 860 acres in 1962. Change in tract size reflected that of contiguous blocks, but the change was not always proportional because number of tracts did not vary directly with acreage changes.

Most fragmentation took place in the two most heavily forested zones (4 and 5), while the shift in zone 1 between 1946 and 1962 was negligible. The net change in zone 2 was toward consolidation but, like zone 3, which showed evidence of fragmentation, the net change was not large and most of it occurred after 1954.

Although the average size of contiguous blocks and tracts did not change much for the study area as a whole, net shifts in forest zones 4 and 5 were fairly large. The average size decreased by about one-third in both of these zones. Such changes are particularly significant when we consider that zones 4 and 5 include a major share of northern Lower Michigan's timber-growing potential.

Marketing and logging costs can well be affected by the spatial distribution and size of individual tracts of timber. Other things being equal, a 200-acre block of timber would be more economical to harvest than five 40-acre blocks.[4] For one thing, there would be fewer owners to contact and deal with, resulting in lower fixed cost per unit volume harvested. Also, access roads can be laid out more efficiently where large properties are involved. It therefore follows that the cost of harvesting and marketing forest products will increase with an increase in forest land fragmentation.[5]

[4] *This statement cannot be supported by empirical data, but it is logical and is presumed to be true by wood procurement men.*

[5] *This would hold true up to a point. Where there were few woodland owners, prices for stumpage could conceivably be administered to a level where economies of large-scale logging were offset by high stumpage costs.*

TABLE 1. — *Change in forest acreage in contiguous blocks and tracts, 1946-1962*

Zone (percent of forest[1])	Average number of acres					
	1946		1954		1962	
	Block	Tract[2]	Block	Tract[2]	Block	Tract[2]
1 (40-55)	306	40	306	40	302	40
2 (56-65)	311	54	317	54	371	62
3 (66-75)	1,321	221	1,332	221	1,298	211
4 (76-85)	1,090	317	801	229	699	205
5 (86 plus)	1,230	315	920	235	906	217
Average	979	182	881	164	860	156

[1] *Based on 1955 Forest Survey data.*
[2] *Calculated by dividing the total forest area within contiguous forest blocks by the respective number of contiguous forest tracts.*

To put the concept in economic terms, if ownerships are getting smaller and smaller, the marginal cost curve for each woodlot will shift to the left (fig. 5). Since a timbershed's supply curve represents a horizontal summation of all the producers' marginal cost curves, fragmentation of forest properties would reduce the economic supply of timber. Of course, consolidation of forest land would tend to increase the economic supply of timber products, other things being equal.

Breakup of Large Forest Ownerships Reduced Average Size

The breakup of relatively large forest ownerships accounted for much of the fragmentation between 1946 and 1962 (fig. 6). But the trend toward smaller properties involved all ownership sizes. For example, approximately 36 percent of the change in block size can be attributed to the breakup of medium and small properties.

The breakup of large ownerships does not necessarily mean that we have less acreage in large holdings. What it does mean is that individual large ownerships are not as large now as in 1946. Conceivably we could have more acreage in large forest ownerships, while at the same time having smaller contiguous blocks. Although this was not the case in the study area, the findings suggest that the area in large forest ownerships did not change much during the 1946-1962 period. As the tabulation below shows, the acreage of large ownerships for all zones decreased by only 7 percent between 1946 and 1962:

Zone	*Index of large forest ownership acreage, 1946 = 100*		
	1946	*1954*	*1964*
1	*	*	*
2	100	1,200	4,100
3	100	102	102
4	100	81	17
5	100	62	62
All zones	100	93	93

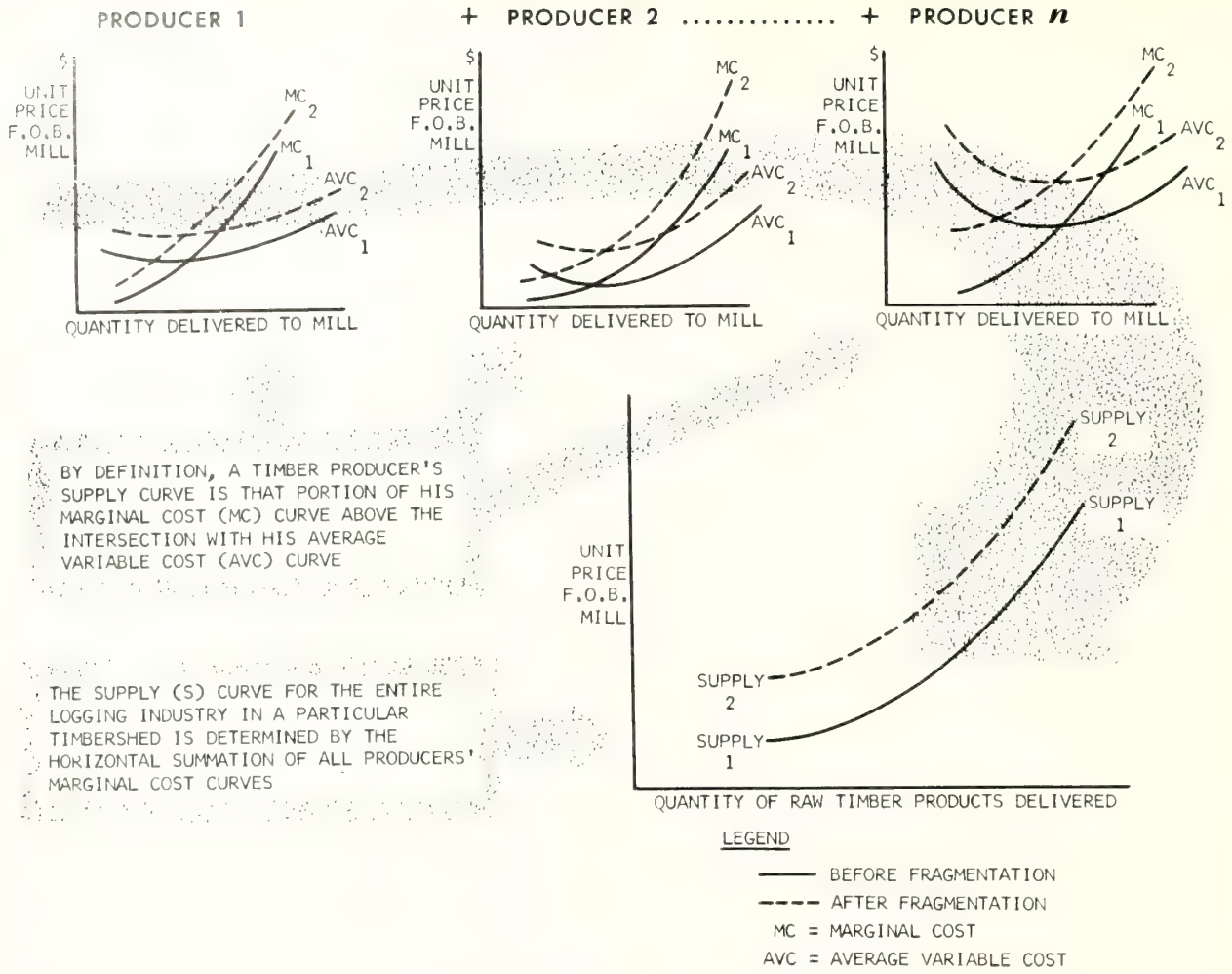
* *There were no large ownerships in my sample of Zone 1.*

The "all zones" figure, of course, masks out some rather drastic but conflicting shifts. For instance, the 1962 acreage in zone 4 was only 17 percent of the 1946 figure. Zone 5 also exhibited sizable change. But fragmentation of large ownerships in these two zones was nearly balanced by consolidation in zone 2, resulting in only a slight change for the entire study area. On the other hand, the spatial distribution of large ownerships in 1962 differs from that in 1946. Whereas fragmentation involved the breaking up of several large blocks of forest land, the "new" large ownership acreage in zone 2 involves relatively small, scattered tracts.

Change in Block Size Not Related To Farming or Nearness to Cities

One might suspect the change in size of contiguous forest blocks to be related to agricultural activity, since Lake States farm units have been enlarging during postwar years.[6] But more importantly, the intensive

[6] *Dean N. Quinney, and Con H Schallau, Lake States Forest Lands in a Changing Economy.* Land Economics *39(4): 421-427. 1963.*


PRODUCER 1
+ PRODUCER 2 ..... + PRODUCER n
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UNIT PRICE F.O.B. MILL
MC 2
MC 1
AVC 2
AVC 1
QUANTITY DELIVERED TO MILL
BY DEFINITION, A TIMBER PRODUCER'S SUPPLY CURVE IS THAT PORTION OF HIS MARGINAL COST (MC) CURVE ABOVE THE INTERSECTION WITH HIS AVERAGE VARIABLE COST (AVC) CURVE
THE SUPPLY (S) CURVE FOR THE ENTIRE LOGGING INDUSTRY IN A PARTICULAR TIMBERSHED IS DETERMINED BY THE HORIZONTAL SUMMATION OF ALL PRODUCERS' MARGINAL COST CURVES
SUPPLY 2
SUPPLY 1
QUANTITY OF RAW TIMBER PRODUCTS DELIVERED
LEGEND
BEFORE FRAGMENTATION
AFTER FRAGMENTATION
MC = MARGINAL COST
AVC = AVERAGE VARIABLE COST

FIGURE 5. — A hypothetical demonstration of how fragmentation can affect the economic supply of timber. Fragmentation, assuming all other factors constant, causes a shift of producers' (No. 1, No. 2,. .. No. n) marginal cost (MC) curves. This in turn is reflected by the logging industry's supply (S) curve being shifted from S_1S_1 to S_2S_2.

agricultural areas have less forest land and, therefore, less chance for consolidation or fragmentation to occur. The opposite would apply to the extensive agricultural zones.

As logical as this hypothesis might seem, a statistical analysis (table 2) showed no significant relationship between change in size of contiguous forest blocks and agricultural activity as measured by the acreage of cropland harvested (X_4).[7] These results do not rule out the possibility of some forest land consolidation accompanying farm unit consolidation. However, I feel it is safe to say such shifts are unimportant from the aggregate standpoint.

Distance from Interstate Highway 96 (X_7) was used to measure a sample section's proximity to metropolitan Michigan. I thought reduction in size of contiguous blocks might be positively related to distance while consolidation would occur further south where farming is more prevalent. However, table 2 discloses that distance had little or no bearing on fragmentation or consolidation.

[7] *This as well as other statistical analyses reported here was processed at the Numerical Analysis Center of the University of Minnesota. The CDC UMSTAT 50 program was utilized.*

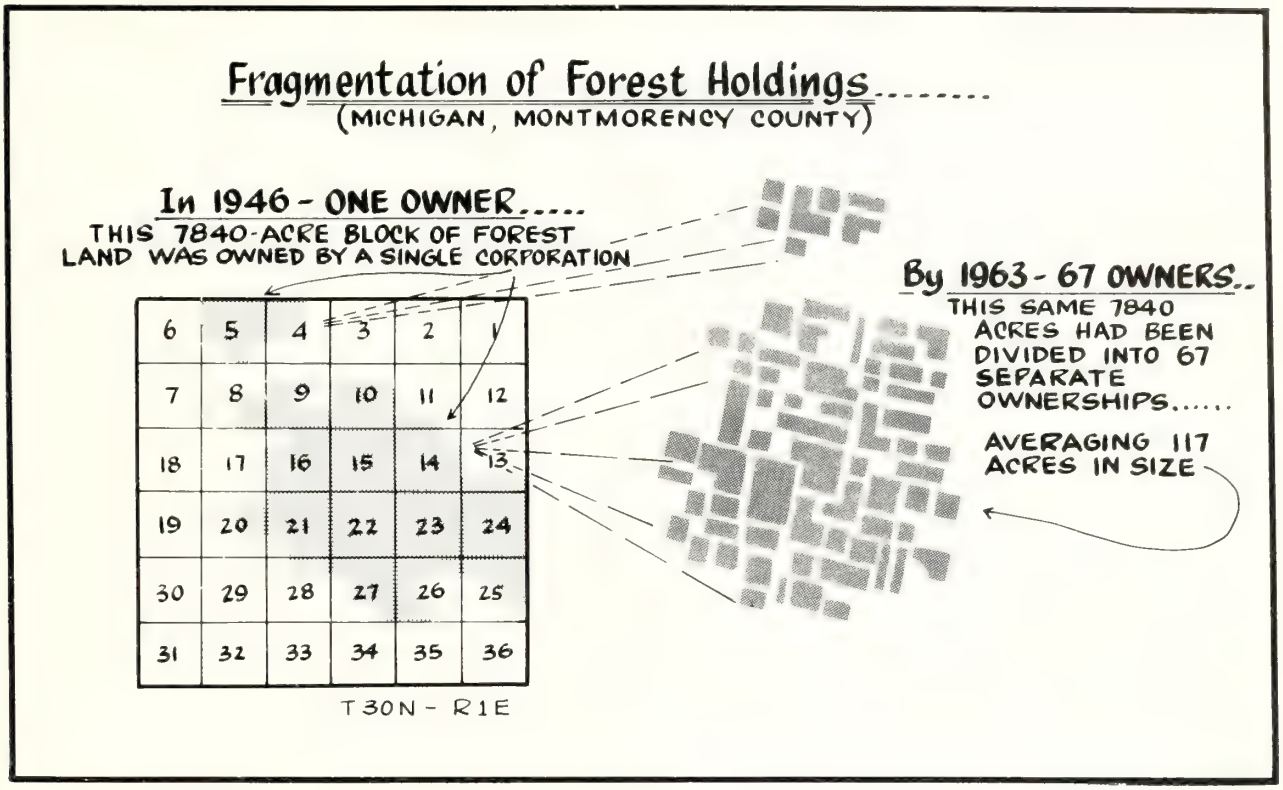
Fragmentation of Forest Holdings.....
(MICHIGAN, MONTMORENCY COUNTY)
In 1946 - ONE OWNER.....
THIS 7840-ACRE BLOCK OF FOREST LAND WAS OWNED BY A SINGLE CORPORATION
By 1963 - 67 OWNERS..
THIS SAME 7840 ACRES HAD BEEN DIVIDED INTO 67 SEPARATE OWNERSHIPS.....
AVERAGING 117 ACRES IN SIZE
6 5 4 3 2 1
7 8 9 10 11 12
18 17 16 15 14 13
19 20 21 22 23 24
30 29 28 27 26 25
31 32 33 34 35 36
T30N - R1E

FIGURE 6. — The more dramatic 1946-1962 shifts in the size of forested tracts were associated with changes in large forest ownerships. But smaller properties also were broken up into still smaller ones.

Subdivision for Summer Homesites Not Too Important

Before undertaking this study I had observed occasional instances in plat books where forested descriptions had been subdivided into very small tracts. Usually this indicated summer home sites. A statistical analysis shows that subdividing (X_6) was not related to major shifts in size of contiguous forest blocks. Subdivision between 1946 and 1962 didn't account for much of the 1946 forest land base — less than 2 percent of the study area's total acreage.[8]

[8] *Sampling was restricted to forest land as defined by Forest Survey specifications, so this subdivision does not include that taking place within incorporation limits or developed lake frontage as of 1946.*

We have already seen that breakup or consolidation of relatively large forest ownerships was responsible for much of the change in size of contiguous forest blocks. The statistical analysis amplifies this point. The beta coefficients in table 2 show that change in large forest ownership area (X_9) accounted for more variation in change in block size than all other variables tested.

Two other variables were significantly associated with changes in size of contiguous forest blocks: (1) the size of contiguous forest blocks at the beginning of the study period (X_1), and (2) the change in acreage of absentee ownership (X_{10}). At first the relationship between X_1 and the independent variable might appear rather obvious. But until the data were collected and analyzed there was no basis to judge whether one size class of properties (in this case the large ownerships) had an edge or not.

TABLE 2. — *Factors associated with change in size of contiguous forest blocks (Y), 1946-1962[1]; all forest zones combined*

Multiple correlation coefficient	.6726
Standard error of estimate	610.2630

Independent variable	Regression coefficient	Standard error	Beta coefficient[2]
Constant term	—166.9909		
Size of contiguous forest block in 1946 (X_1)	.0310**	.0127	.1302
Acreage of public ownership in sample section in 1946 (X_2)	.0731	.2122	.0193
Acreage of large private ownership in sample section in 1946 (X_3)	.1985	.6617	.0187
Average acreage of cropland harvested per section in 1959 (X_4)[3]	.1508	.5596	.0126
Acreage of absentee ownership in sample section in 1946 (X_5)	—.1345	.3339	—.0264
Acreage of forest land subdivided for residential or summer home sites between 1946 and 1962 (X_6)	—.5106	1.8930	—.0114
Distance from Interstate Highway 96 (X_7)	.9457	1.7760	.0248
Private forest area as a percent of total land area in 1946 (X_8)	30.8970	20.0910	.1175
Change in large forest ownership acreage between 1946 and 1962 (X_9)	7.6350**	.6412	.5834
Change in absentee ownership acreage between 1946 and 1962 (X_{10})	—1.2523**	.3509	—.1801

[1] *Form of equation used was* $Y = a + b_1X_1 + b_2X_2 \ldots b_nX_n$. *None of the variables was transformed.*

[2] *Cf., Palmer O. Johnson,* Statistical Methods in Research, *Prentice-Hall, New York, 1949, p. 329 . . . "the B's are the partial regression coefficients for the variates expressed in standard measure form, thus rendering them independent of the original units of measurement and giving measures of the comparative weight attributable to each of the independent variates."*

[3] *Magnitude of this variable ranged from 1 to 382 acres per sample section. Township data obtained from Census of Agriculture.*

** *Significant at .01 level.*

Fragmentation Likely to Continue

Because of hunting opportunities, and the demand for outdoor recreation in general, landownership in the study area has become attractive to nonresidents. This interest has led to fragmentation in the past and has also increased land costs. Land acquisition policies of one wood-using firm have been responsible for most forest land consolidation. But because of increased land costs it is doubtful that such companies will want to buy much more land. That fragmentation will continue to determine the trend in size of contiguous forest blocks seems a safe assumption.

Absentee Ownership Likely a Determinant of Timber Availability

For the study area as a whole, acreage of absentee ownership[9] increased about 45 percent between 1946 and 1962 (table 3). Zone 5, the most heavily forested, stands out both in terms of total acreage and absolute change in absentee ownership. But the important observation is that absentee ownership increased in all other zones and at greater rates. For instance, absentee ownership in zone 2 increased by 65 percent but only by 35 percent in zone 5.

TABLE 3. — *Change in acreage of absentee ownership, 1946-1962*
(Acres)

Zone	Absentee ownership per section		
	1946	1954	1962
1	42.5	53.3	67.2
2	79.8	102.0	132.9
3	93.2	111.3	133.0
4	71.5	82.4	107.9
5	185.3	220.1	249.0
All zones	100.0	120.0	144.2

A statistical analysis (table 4) disclosed that the acreages both of large private (X_3) and publicly owned (X_2) forest area in a sample section in 1946 were significantly associated with change in absentee ownership. The negative signs of these two coefficients can be explained by the fact that most private ownership in areas where public and large private ownership predominated in 1946 was already absentee and subsequent changes resulted in an increase of resident ownerships. The analysis also showed change in absentee ownership was more likely in areas where the acreage in large ownerships *changed* (X_{10}). Further, areas having absentee acreage in 1946 (X_5) continued to "attract" the nonresident.

Distance from metropolitan Michigan (X_7) was also associated with change in absentee ownership. The farther a sample section was from the metropolitan areas, the more absentee acreage changed.

The effect of absentee ownership on timber availability is not easy to appraise. Absentee owners are probably less likely than resident owners to be dependent on their forest as a source of income. Perhaps this is one reason why studies have shown the nonresident to be less inclined to market timber. In the Upper Peninsula, for instance, Quinney found that more than 50 percent of forest landowners residing there had harvested timber, whereas only 11 percent of the nonresidents had.[10] In southern Michigan nearly 40 percent of the owners who lived within 10 miles of their wooded tract had harvested timber at least once during their tenure, while only 7 percent of the remaining owners had done so.[11]

One might think that perhaps resident owners have more valuable timber than the absentees and, therefore, are more likely to sell some. But this doesn't appear to be the case. Yoho, for instance, found that, "timber stand conditions have no consistent relationship with owner's distance from property."[12] In fact, the nonresident in southern Michigan had more valuable timber. Only 17 percent lived more than 10 miles from their woodland property, but this group owned 22 percent of the growing stock value.

Certainly, in the short run at least, the tendency for absentee owners to harvest less often may restrict timber supply. But then there is the matter of owner receptiveness to timber management. The experience of some foresters operating in the study area suggests that the nonresident owner is more likely to

[9] *An owner was judged "absentee" if he lived at least 15 miles from his forest property. I assumed this to be the minimum distance affecting timber sale negotiation.*

[10] *Quinney, Dean N. Small private forest landowners in Michigan's Upper Peninsula. Lake States Forest Expt. Sta., Sta. Paper 95, 20 pp., illus. 1962.*

[11] *Schallau, Con H. Small forest ownership in the urban fringe area of Michigan. Lake States Forest Expt. Sta., Sta. Paper 103, 17 pp., illus. 1962.*

[12] *Yoho, James G. Private forest landownership management in the northern half of Michigan's Lower Peninsula. Mich. State Univ. Agr. Expt. Sta. Tech. Bul. 261. 1957. (See p. 23.)*

TABLE 4. — *Factors associated with change in absentee ownership (Y) in sample sections between 1946 and 1962; all forest zones combined*

Multiple correlation coefficient	.5997
Standard error of estimate	94.9097

Independent variable	Regression coefficient	Standard error	Beta coefficient
Constant term	15.7873		
Size of contiguous forest block in 1946 (X_1)	.0002	.0020	.0071
Acreage of public ownership in sample section in 1946 (X_2)	—.0914**	.0326	—.1680
Acreage of large private ownership in sample section in 1946 (X_3)	—.1801*	.1024	—.1179
Average acreage of cropland harvested per section in 1959 (X_4)	.0969	.0869	.0056
Acreage of absentee ownership in sample section in 1946 (X_5)	.4728**	.0447	.6458
Acreage of forest land subdivided between 1946 and 1962 (X_6)	.3810	.2936	.0589
Distance from Interstate Highway 96 (X_7)	.5688*	.2745	.1039
Private forest area as a percent of total land area in 1946 (X_8)	—2.6517**	.2767	—.7013
Change in size of contiguous forest blocks between 1946 and 1962 (X_9)	—.0303**	.0085	—.2106
Change in large forest ownership acreage between 1946 and 1962 (X_{10})	.3078**	.1184	.1636

* *Significant at .05 level.*
** *Significant at .01 level.*

subscribe to harvesting and management proposals. Many absentee owners are interested in deer hunting; in fact, this often is the main reason for their owning forest land. Cutting usually improves browse conditions, so such owners occasionally welcome the opportunity to sell timber. Conceptually, in such instances timber products can best be described as "by-products of deer production."

Absentee owners are less likely to be interested in agricultural production. As a result, probably less forest land will be used for crop and pasture purposes as absentee ownership increases.

Property Rights in Forest Land In Continual State of Flux

Forest management is more compatible with stable tenure than rapid turnover, other things being equal. For instance, a person who cannot foresee holding his forest property until it will support a timber harvest isn't likely to be very interested in timber stand improvement or tree planting, unless it clearly improves the value or marketability of his property. Also, the lasting effect of private

and public forestry assistance programs is jeopardized by rapid turnover of forest property.

Most privately owned forest land had two owners during the 16-year period (table 5). Sixteen percent of the forest area had three owners. The turnover of forest property was fairly uniform throughout the study area except for zone 4 which had a considerably more rapid turnover.

TABLE 5. — *Percent of forest area in sample section having single or multiple owners during 1946-1962 period*

Zone	One owner	Two identified[1] owners	Three identified[1] owners
1	46	45	9
2	45	44	11
3	40	44	16
4	22	50	28
5	41	40	19
All zones	40	44	16

[1] *I compared owners' names at three points in time — 1946, 1954, and 1962. Chances are most owners' tenure overlapped one of these time periods, but some ownerships that were acquired and sold during intervening years may have been missed. For this reason I feel it best to add the term "identified" when referring to multiple ownerships.*

Discussion and Conclusions

This study has shown private forest-land ownership in the northern half of the Lower Peninsula of Michigan to be very dynamic. The few changes measured are evidence enough. When one considers that these and others are all occurring at the same time and at different rates and in different directions, the situation becomes more involved.

The material presented here may lead the reader to believe that the cost of supplying timber will necessarily increase. I don't want to leave this impression.

For one thing, the forest resources of northern Michigan are staging a comeback. Increased stocking and growth rates should tend to lower harvesting costs per unit volume. In addition, property turnover as well as absentee ownership can sometimes increase the economic supply of timber. If a large forest tract is owned by someone who prefers not to sell stumpage — and there are examples of this — then the breakup of such a property might be good from the timber supply standpoint. At least a few of the new owners might be willing to sell timber.

Cost-decreasing features of the land use changes discussed here might well equal or exceed the cost-increasing side. However, the mere existence of cost-increasing features should challenge foresters and timber users to seek more efficient ways to market and manufacture timber products.

In this study I have merely identified certain forest ownership changes. What these results imply relative to future timber supplies has not been resolved and must be established in later work.

(See page 12 for Appendix)

Appendix: Sampling Accuracy

Table 6 gives an example of the statistical accuracy achieved in this study. Another method used for checking accuracy is to compare estimates with other independently determined values. I was able to make certain comparisons with Forest Survey statistics as follows:

Mean estimate	*Fragmentation study*	*Forest Survey*
Percent of privately owned land that is forested	59.2	61.9
Public ownership as a percent of total land area	24.1	24.3
Large private forest ownership as a percent of total private forest land	4.9	5.7

TABLE 6. — *Examples of sampling accuracy obtained, all zones combined*
(In acres)

Item	1946		1954		1962	
	$\overline{X}$	$S_{\overline{x}}$	$\overline{X}$	$S_{\overline{x}}$	$\overline{X}$	$S_{\overline{x}}$
Average size of contiguous forest blocks	979	187	881	186	860	181
Large forest-land ownership per section	15	4	14	4	14	4
Absentee ownership per section	100	9	120	9	144	10

Some Recent Research Papers In the Lake States Station Series

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Thinning Red Pine for High Investment Returns

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Contents

Page

THE THINNING ALTERNATIVES EXAMINED 2

EVALUATION OF INVESTMENT ALTERNATIVES 4

EFFECT OF STAND DENSITY ON INVESTMENT RETURNS UNDER VARIOUS CONDITIONS 5

- Site Index and Initial Stand Conditions 6
- Discount Rates and Costs 6
- Markets 8
- Timber Quality 9
- Summary 10

BASAL AREA DENSITIES LOWER THAN 90 SQUARE FEET 11

FINANCIAL ROTATION AGE 11

- Estimation of Financial Rotation Age 11
- Factors Affecting Financial Rotations 12
- Some Suggested Financial Rotation Ages 14

A FINAL WORD 18

LITERATURE CITED 19

Thinning Red Pine for High Investment Returns

by Allen L. Lundgren

Red pine (*Pinus resinosa* Ait.), a favored timbered species in the Lake States, is well-suited to intensive, even-aged silviculture. Comparatively free of serious damage by insects and diseases, it responds well to thinning (fig. 1). However, because red pine can be thinned in many ways to grow a number of salable products, the forest manager may have difficulty deciding just how a stand should be thinned to best attain the owner's goals.

In both public and private forestry an important goal is to earn the highest possible return on capital invested in growing timber; this indicates that capital resources are being used efficiently. To meet this goal, foresters growing red pine must know how silvicultural practices and other management conditions affect investment earnings.

Of the many factors involved, some, such as thinning practices and rotation lengths, can be controlled by the forest manager. Others, such as the amount of capital invested, initial stocking, and site selection, may be under his control only at certain times. Still others, such as stumpage prices and the cost of capital, may be beyond his control. Thus the forest manager can influence investment returns to some extent, but only within certain limits.

This paper is written for the professional forest land manager. It explains how two factors that can be controlled, thinning practices and rotation ages, affect investment returns from growing red pine. It demonstrates that, under almost any conditions, investment returns are highest if stands are thinned regularly to 90 square feet of basal area per acre, the lowest density evaluated. It shows how financial rotations, which must be estimated in evaluating thinning alternatives, vary widely with stand conditions, investment alternatives, costs, and prices, and suggests financial rotation ages for certain stand conditions commonly found in the Lake States.

F-500542

FIGURE 1. — Red pine responds well to a variety of thinning practices and can be cut for many products.

Note: Dr. Lundgren is an Economist on the staff of the Lake States Forest Experiment Station. His headquarters are at the Station's Laboratories and Main Office, which are maintained by the Forest Service, U.S. Department of Agriculture, on the St. Paul Campus in cooperation with the University of Minnesota.

The Thinning Alternatives Examined

The volume growth of red pine stands varies with site and stand conditions. On a given site, early growth can be controlled to some extent by the initial spacing of trees (through planting or early thinning) and by release and other cultural practices. These will determine the density (basal area) and stocking (number of trees) during the early years in an established stand. Once a stand is established, its future growth can be greatly influenced by thinning (fig. 2).

The early choice of a thinning schedule is important, because each thinning sets in motion a new sequence of growth that in the future can be altered only within certain limits. The influence of any past thinning practices can never be eliminated completely by subsequent thinnings. Thus, any proposed program of thinning should be evaluated over an entire rotation to insure that early thinnings do not create a less desirable stand for the future.

F-500544

FIGURE 2. — Early thinning in red pine produces pulpwood and other small products such as posts and poles.

The density left after each thinning, the method of thinning, the thinning interval, and the age of the first thinning all affect future volume yields (fig. 3). All can be controlled by the forest manager.

This study evaluates only the basal area left after thinning and its effect on investment returns. Because there is almost no limit to the different kinds of red pine stands and the ways in which they can be thinned, the following examples were selected to represent a wide range of initial stand conditions and thinning programs:

Site index: 45, 50, 55, and 60.

Basal area before thinning at age 25: 60, 90, 120, 150, and 180 square feet per acre.

Number of trees before thinning at age 25: 400, 800, 1,200, and 1,600 per acre.

Rotation ages: 25 to 165 years.

Alternative rates of return: 2 to 8 percent.

Regeneration costs: $0 to $80 per acre.

Markets: (1) Cordwood only
(2) Cordwood and sawtimber with constant stumpage prices
(3) Cordwood and sawtimber with higher prices for larger trees

Many variations in density left after thinning were evaluated: (1) Maintaining a constant basal area of 60, 90, 120, or 150 square feet per acre throughout the rotation, and (2) varying the basal area throughout the rotation by allowing it to increase, decrease, or vary irregularly. However, basal areas of 60 square feet after thinning, and initial densities of more than 90 square feet of basal area with only 400 trees per acre are not reported here because they were not well supported by field data. Thinning schedules that allowed the basal area to vary throughout the rotation also were dropped. Only rarely did these give higher investment returns than constant basal areas; furthermore, they would be more complicated to apply in the field.

Therefore, the thinning alternatives considered here are constant levels of basal areas from 90 to 150 square feet per acre maintained throughout the rotation.

F-511226

FIGURE 3. — Red pine stands thinned to low densities (90 square feet) grow faster in diameter and produce saw log thinnings 20 years earlier than stands maintained at high densities (150 square feet).

The thinning method chosen was one commonly used: thinning from above-and-below. With this method both large and small trees are cut at each thinning so that the average stand diameter is not changed by thinning and the remaining stand of trees is well-spaced.[1] Stands were thinned every 10 years, beginning at age 25 if the basal area at that time was above the desired level.

For each site, stand condition, and thinning schedule to be evaluated, cordwood and board-foot volume yields from thinnings and from final harvest cuts at each age were computed. These were developed from the basal area growth and total cubic-foot volume yields which were estimated from growth equations based on permanent sample plots and reported by Buckman (1962). Total cubic-foot volumes were converted to cordwood volumes at 9.7 cords per thousand cubic feet (from Buckman's (1962) cubic-foot and cordwood volume ratio estimates).[2] Average stand diameters at each age were estimated for each schedule from basal area growth and known numbers of trees. Conversion factors were applied to cubic-foot yields to get board-foot yields.[3] These factors, varying with average stand diameter and height, were estimated from data given by Gevorkiantz and Olsen (1955). In all, more than 500 volume yield tables were constructed and evaluated.

Because growth data for stands younger than 25 years are not yet available in sufficient detail, initial stand conditions are described in terms of the basal area and number of trees per acre at age 25 before thinning. The range of initial basal areas and numbers of trees studied covers most variations likely to occur at that age in Lake States stands. Information on the growth of large-diameter trees is limited, so a rotation was ended whenever trees would exceed 25 inches in diameter. This restriction had no impact on thinning decisions, and only rarely on rotation age decisions.

The following merchantability standards were set:

1. All stands averaging less than 4.6 inches diameter breast high (d.b.h.) are nonmerchantable.
2. In stands averaging 4.6 inches or larger in d.b.h., all trees can be cut as cordwood.
3. In stands 9.1 inches or larger, all trees can be cut as saw logs.
4. Yields of less than 2 cords or 1,000 board feet per acre are nonmerchantable.

Future yields are assumed to be known with certainty, and are not reduced for risk of catastrophic loss by fire or other agents.

In summary, the thinning alternatives to be examined are constant levels of stand density from 90 to 150 square feet of basal area per acre to be left after each thinning at 10-year intervals over a range of sites, initial stand conditions, rotation ages, costs, prices, and alternative rates of return.

[1] *In this paper the average stand diameter is the diameter breast high (d.b.h.), outside bark, of the tree of average basal area.*

[2] *Rough cords in trees 3.6 inches d.b.h. and larger to a 3.0-inch top d.i.b. (diameter inside bark).*

[3] *International ¼-inch rule in trees 7.6 inches d.b.h. and larger to a 6.0-inch top d.i.b.*

Evaluation of Investment Alternatives

Land expectation values (LEV) are used to evaluate alternative thinning schedules and rotations under various costs, prices, and stand conditions.[4] This measure of investment return is the present value (the value at the beginning of a rotation) of the discounted net income expected from an investment. Each thinning schedule and rotation age under each set of cost, price, and other conditions is considered a separate investment alternative. For each investment, all costs and incomes during one rotation are discounted back to the time of stand establishment. Subtracting discounted costs from discounted incomes gives the present value of an investment for one rotation. Multiplying this present value by a special interest rate factor, which allows for a land value left at the end of the rotation, gives the LEV.[5] The thinning schedule resulting in the highest LEV earns the highest return (net income) on capital invested during the rotation. All returns reported here are before income taxes.

In discounting costs and incomes, the alternative rate of return should be used. This is the rate of compound interest that could be earned on the money or capital if it were invested elsewhere. It is the price of the capital used in the investment. The alternative rate used should be realistic, because in calculating the present value it is assumed, in effect, that all extra investment funds and all income from growing red pine can be reinvested at this rate.[6] We will assume that the alternative rate, the cost of capital, is known.

Incomes from thinnings and from final harvest cuts are estimated for each thinning alternative by multiplying volume yields by expected stumpage prices. Three basic stumpage price schedules are considered:

1. *Constant cordwood price* — where only cordwood can be sold at a constant stumpage price regardless of stand characteristics.
2. *Constant sawtimber price* — where both cordwood and sawtimber can be sold at a constant price per cord and per thousand board feet.
3. *Varying sawtimber price* — where both cordwood and sawtimber can be sold, but prices vary with average stand diameter (d.b.h.) according to the following formulas:

   $(½ dbh — 1) per cord
   $(dbh + 5) per thousand board feet
   $2 per cord in tops of sawtimber trees.

The constant cordwood price market places no premium on tree size, but values equally all merchantable cubic-foot volume regardless of stand composition. The constant sawtimber price market places a premium on growing large-diameter trees, because there are more board feet per cubic foot of total volume in larger diameter trees. It places a further premium on growing sawtimber sized trees because a cubic foot of wood is usually worth more as sawtimber than it is as cordwood. The varying sawtimber price market places an even higher premium on growing larger diameter trees, because cordwood prices increase $0.50 per cord and sawtimber prices $1 per thousand board feet for each one-inch increase in average stand diameter.

Although realistic for parts of the Lake States, the price schedules used are not meant to represent actual market conditions expected in growing red pine. Rather, they cover a wide range of possible prices to test the effect of extreme differences in future markets on present thinning and rotation age decisions.

Two classes of costs are considered: annual management expenses, and regeneration (stand establishment) costs (which include site preparation, planting, release, and pruning). All future costs during the rotation are discounted back to the time of stand establishment, using the specified discount rate. No distinction is made among regeneration costs. We are interested in how costs

---

[4] *The merits of this and other methods of evaluating investment alternatives have been debated at great length in the literature. Those wishing more information on this are referred especially to Thomson (1942), Chapman (1950), Davis (1954), Hiley (1956), and Gaffney (1957).*

[5] *The multiplier used is* $\frac{(1+p)^n}{(1+p)^n-1}$, *where* p *is the discount rate and* n *is the rotation length in years.*

[6] *Duerr, Fedkiw, and Guttenberg (1956, pp. 4 and ff.) discuss how to determine the alternative rate of return. See also Duerr (1960, pp. 143 and ff.).*

in general will affect thinning and rotation age decisions; for this purpose it makes no difference whether a cost is a discounted release cost or a site preparation cost so long as it results in the same kind of red pine stand at a given age. Regeneration costs from $0 to $80 per acre and a range of annual expenses are considered. No other costs are included. Stumpage prices are assumed to be net of any special sales costs.

Because the rotation age affects the expectation value of the red pine timber growing investment, it must be considered even when a stand is just being established. However, in estimating a rotation age to use in evaluating a future stand the purpose is not to set one which future managers must follow. Rather, it is to insure that all foreseeable costs and incomes to the end of an investment cycle are included in the appraisal.

This analysis evaluated all possible rotation ages at 10-year intervals from age 25 to 165 years for each thinning opportunity. From these alternative ages, the one giving the highest land expectation value (LEV) was chosen as the financial rotation age, and its LEV was used as the expectation value of the thinning opportunity. By using this financial rotation, which varies from 25 to 165 years depending upon discount rates, costs, prices, and stand conditions, the highest returns obtainable from each investment opportunity are compared. If no rotation is specified, it should be understood that a given LEV is for the financial rotation age.

This financial rotation is used with the expectation that it will be the one chosen by a manager seeking the highest return on his investment. A manager with this aim would end a rotation whenever the capital in a stand left after thinning will no longer earn the alternative rate of interest that could be earned elsewhere. Unless conditions change, the rotation age set in this way is identical with that giving the highest LEV.

To evaluate the three density levels over the range of conditions examined in this paper, about 200,000 land expectation values were computed by an electronic computer, using a special program designed for this study. It would not be possible or desirable to present all these data in this paper. Instead, only the conclusions about stand density and rotation ages will be given, with a few examples as illustrations.

Effect of Stand Density On Investment Returns Under Various Conditions

Through a program of regular thinnings it is possible to control the growing space of individual trees in a red pine stand. Such thinnings are biologically and economically practical. The problem is, how much timber should be left after each thinning so as to earn the highest return on the capital invested in a stand?

For the basal area thinning levels considered here the answer is surprisingly simple. With only a few minor exceptions, thinning red pine stands back to 90 square feet of basal area per acre every 10 years will give a higher investment return over the rotation than thinning back to any higher basal area density (figs. 4 and 5). This is true regardless of the initial density and stocking of the stand, site, discount rate, costs, or stumpage prices. A few examples will illustrate these conclusions.

Let's look first at a red pine stand on a medium site, site index 50. Establishment costs of $40 per acre are expected to result in a well-spaced stand of 800 trees and 120 square feet of basal area per acre at age 25 before thinning. There are no other timber growing costs to be considered. The stand is to be managed for both cordwood and sawtimber with constant prices of $20 per thousand board feet and $2 per cord.

With a 3-percent discount rate, if the stand were thinned every year to 150 square feet of basal area per acre the land expectation value (LEV) would be only $19 per acre (fig.6). If thinned to 90 square feet the LEV would be $50. In fact, from the steepness of the line it looks as though lower basal areas would give even higher returns; however, basal areas of less than 90 square feet are not being considered here.

By the end of the rotation these differences in investment return among densities are even more striking. If this stand is thinned every 10 years and the income from thinnings invested at 3 percent (the rate earned on alternative investments),

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FIGURE 4. — This 40-year-old red pine plantation has just been thinned to 90 square feet of basal area per acre. Stands thinned regularly to this low density will earn a higher return on invested capital than stands thinned to a higher density.

F-509698

FIGURE 5. — This 40-year-old red pine plantation has just been thinned to 150 square feet of basal area per acre. Stands maintained at such high densities earn a relatively low investment return even when grown primarily for pulpwood.

by the end of the 85-year rotation the net income would be $235 per acre higher if the stand is thinned to 90 square feet rather than to 120 square feet. It would be $384 per acre more if maintained at 90 rather than 150 square feet. These are sizable differences in net investment income.

Stand conditions, costs, prices, and other factors may vary, and with them land expectation values, but the conclusion remains the same:

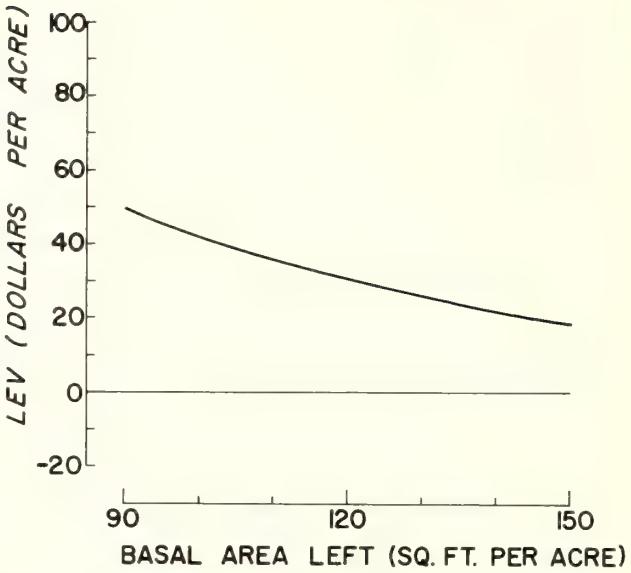

FIGURE 6. — Red pine land expectation values (LEV) are highest at low densities. Site index 50, establishment costs $40 per acre, stumpage prices $20 per thousand board feet and $2 per cord, discount rate 3 percent, 800 trees and 120 square feet per acre at age 25.

thinning to 90 square feet gives higher LEV's than thinning to any higher basal area in every type of stand under almost all conditions.

Site Index and Initial Stand Conditions

The more productive the land, as measured by site index, the higher the expectation value if management costs and stumpage prices are the same. But still, a density of 90 square feet gives the highest investment return on any site from 45 to 60 (at an index age of 50 years), the range of Buckman's (1962) growth equations (fig. 7).

Wide variations in basal area and number of trees per acre before thinning at age 25 greatly alter stand structure, but low-density management gives the highest returns (fig. 8).

Discount Rates and Costs

A change in discount rate changes expectation values, but not the conclusions (fig. 9). With any alternative rate from 2 to 8 percent, a residual basal area of 90 square feet per acre after thinning gives the highest return on investment.

Regardless of whether it costs nothing or $80 per acre to establish a stand, thinning every 10 years to 90 square feet gives a higher return on the invested capital than thinning to any higher density (fig. 10).

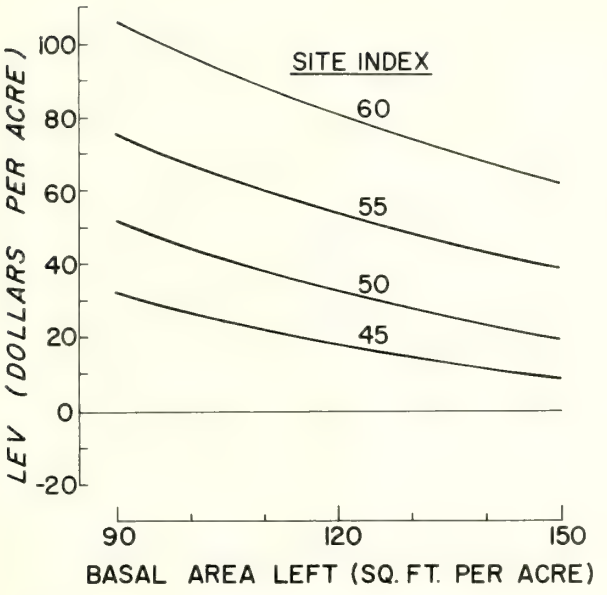

FIGURE 7. — Red pine land expectation values (LEV) are highest at low densities on all sites. Establishment costs $40 per acre, stumpage prices $20 per thousand board feet and $2 per cord, discount rate 3 percent, 800 trees and varying basal areas per acre at age 25.

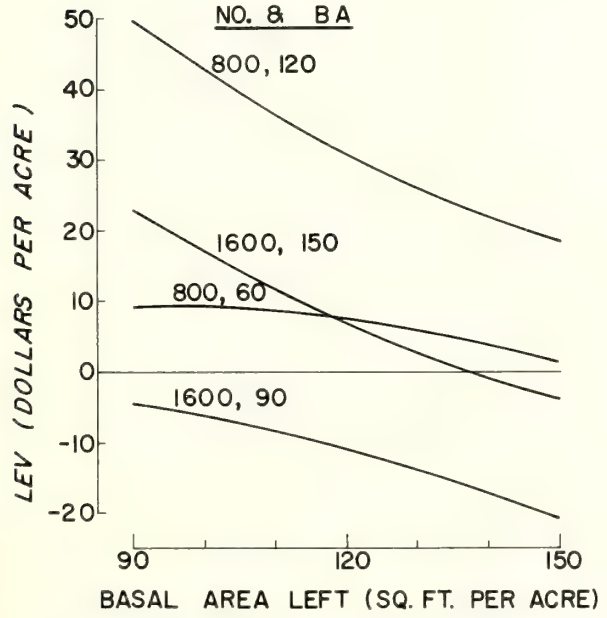

FIGURE 8. — Red pine land expectation values (LEV) are highest at low densities over a wide range of number (no.) of trees and basal area (BA) per acre before thinning at age 25. Site index 50, establishment costs $40 per acre, stumpage prices $20 per thousand board feet and $2 per cord, discount rate 3 percent.

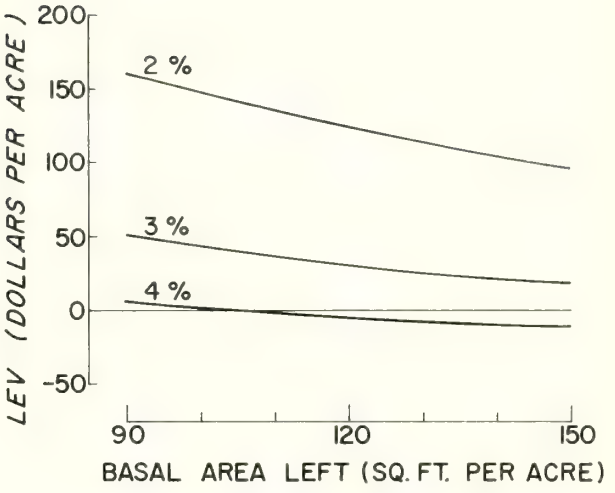

FIGURE 9. — Red pine land expectation values (LEV) are highest at low densities for a range of alternative rates of return. Site index 50, establishment costs $40 per acre, stumpage prices $20 per thousand board feet and $2 per cord, 800 trees and 120 square feet at age 25.

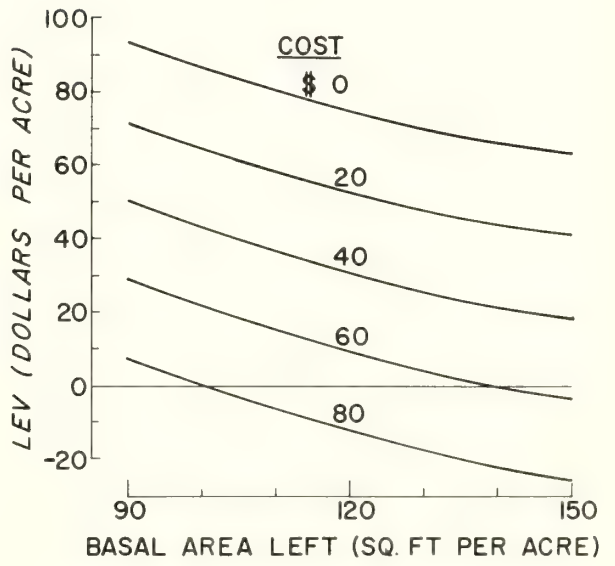

FIGURE 10. — Red pine land expectation values (LEV) are highest at low densities over a wide range of stand establishment costs. Site index 50, stumpage prices $20 per thousand board feet and $2 per cord, discount rate 3 percent, 800 trees and 120 square feet at age 25.

Similarly, if annual management expenses are the same for each density level, then subtracting a constant capitalized expense from each expectation value will not change the relative profitability of the different densities. If the costs differ for each density level, then they should be considered. But there would have to be a big difference to change the conclusions. With a 3-percent alternative rate, management expenses on the site-index-50 example would have to be 60¢ per acre higher each year at the 90 square-foot than at the 120 square-foot density level to make the 120 square feet more profitable. A difference this large is highly unlikely.

Markets

In the constant sawtimber price market, higher or lower stumpage prices per thousand board feet and per cord will not change the choice of stand density. Whether prices are $10 per thousand board feet and $1 per cord or $30 per thousand board feet and $3 per cord, thinning to 90 square feet of basal area per acre still gives higher returns than any higher density (fig. 11). At lower prices the difference in dollars per acre is smaller, but there still is a difference.

The ratio of sawtimber price per thousand board feet to cordwood price per cord used in figure 11 is 10 to 1. Had a larger ratio been used, that is, had sawtimber been valued even more highly in relation to cordwood than it was, the difference between LEV's of 90 and 150 square feet would have been even greater. Had a smaller ratio been used, as in the cordwood-only market where there is no difference in stumpage price between poletimber and sawtimber, the difference would have been smaller. But even here, as we shall see, a density of 90 square feet gives the highest returns in almost every circumstance.

Consider now the market situation where stumpage prices per cord and per thousand board feet increase with tree diameter. The larger the average stand diameter, the higher the price per cord or per thousand board feet. This market places an even greater premium on larger diameter trees than does the constant-sawtimber-price market. Since trees grow more rapidly in diameter in stands maintained at a low density, there is an even greater advantage for thinning to low basal areas.

On site-index-60 land, for example, the LEV for 90 square feet is $72 an acre higher than for 150 square feet, using a 3-percent discount rate (fig. 12). The difference in net incomes between

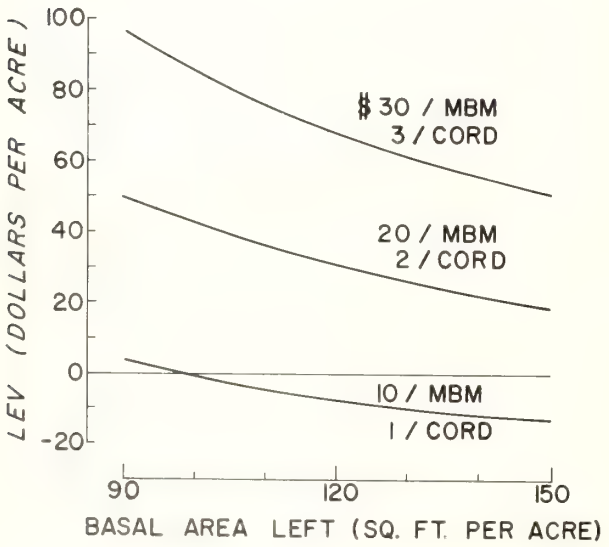

FIGURE 11. — Red pine land expectation values (LEV) are highest at low densities over a wide range of stumpage prices. Site index 50, establishment costs $40 per acre, discount rate 3 percent, 800 trees and 120 square feet at age 25.

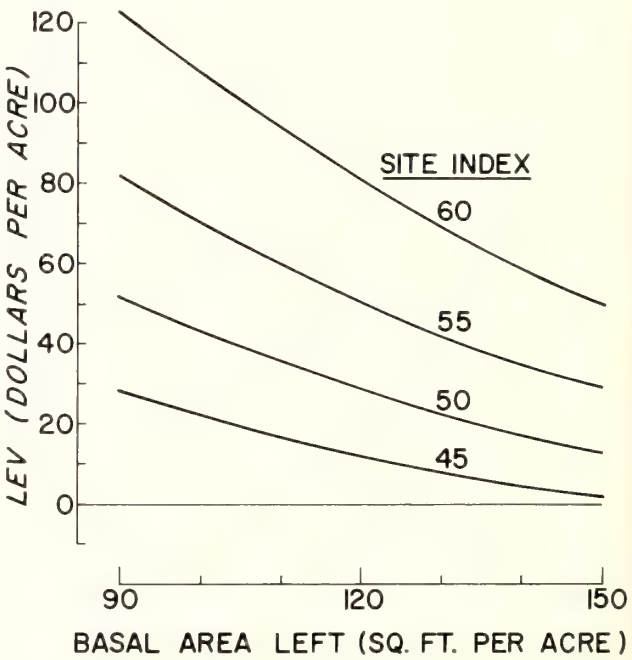

FIGURE 12. — Red pine land expectation values (LEV) are highest at low densities on all sites. Establishment costs $40 per acre, stumpage prices increase with tree diameter, discount rate 3 percent, 800 trees and varying basal areas per acre at age 25.

these two alternatives, invested at 3 percent, amounts to $1,200 per acre by the end of a 95-year rotation.

In still another potential market situation, red pine may be grown for cordwood alone. This market assumes that the stumpage price per cord is the same for any kind of stand regardless of tree size — that it makes no difference in net stumpage price whether twice as many trees must be marked and cut to get one cord of wood in one stand as in another. In many respects this is not a realistic market; yet it was chosen for this very reason. How are choices of stand density affected by such extreme market conditions, where prices are unaffected by tree size and the emphasis is on growing cubic-foot volume?

Even under these extreme conditions, a density of 90 square feet still gives the highest returns for almost all conditions (fig. 13). Exceptions occur if discount rates and costs of establishment are very low. On site index 50, for example, with $4 per cord stumpage, a discount rate of 2 percent, and no establishment costs, the LEV is $113 per acre if 120 square feet are left compared to $112 per acre if 90 square feet are left. Under these unlikely conditions the difference is only $1 per acre. With any establishment costs or with higher rates, 90 square feet would give equally high or higher LEV's than 120 square feet. If higher net stumpage prices are expected for larger diameter trees, through a reduction either in sale preparation costs or in logging costs, then low-density management will be more profitable because trees will grow faster in diameter.

We have assumed that prices will remain unchanged over the rotation. It may be, however, that they will rise at some specified rate, say 1 percent annually. Will such a rise have any effect on the choice of 90 square feet as giving the highest return on investment?

A rise in future stumpage prices of 1 percent is roughly the same as a reduction in the alternative rate of return of 1 percent.[7] As we have already seen, reducing the discount rate will not change our choice of 90 square feet of basal area to be left after thinning.

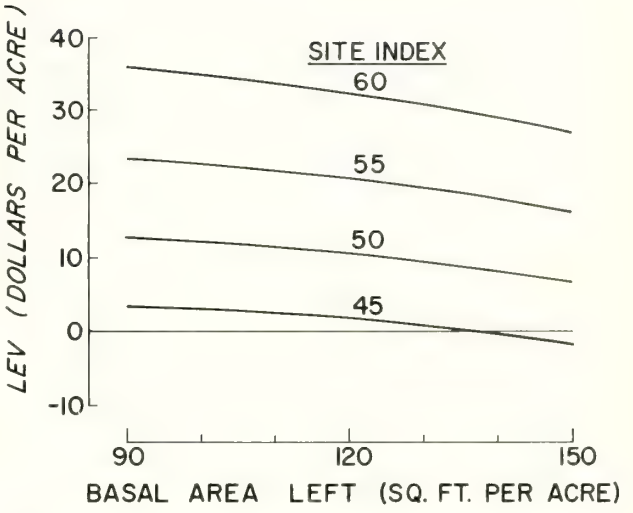

FIGURE 13. — Red pine land expectation values (LEV) in stands grown for cordwood are highest at low densities for all sites. Establishment costs $40 per acre, stumpage price $4 per cord, discount rate 3 percent, 800 trees and varying basal areas at age 25.

Timber Quality

One last price consideration remains — stumpage price variations with density. Some foresters insist that timber grown at a more open spacing — a lower density — is less valuable than timber grown at higher densities; it may have poor form, bigger knots, or other defects. They may be reluctant to thin stands back to 90 square feet of basal area per acre, fearing that diameter growth in such low-density stands will be too fast for good-quality wood.

If a general consensus emerges from the literature on this subject it is this: Conifer trees with from 6 to 8 rings per inch have about as high a specific gravity as trees of the same age that have been grown at a slower rate and thus have more rings per inch (Spurr and Hsiung 1954, Paul 1957, Ralston and McGinnes 1964). Although slow-grown trees may be more desirable in some respects, trees with from 6 to 8 rings per inch are

[7] *This approximation underestimates present values by a small percentage. The underestimate is greater for higher alternative rates of return, higher rates of price increase, and longer discount periods. The discounted value of a single return in 10 years, with prices increasing at 1 percent a year and with a 2-percent alternative rate of return, is underestimated by less than 0.1 percent. For a 2-percent price rise and a 5-percent alternative rate, the underestimate of a single value discounted over 50 years is 2.8 percent, while for prices increasing 3 percent a year and a 6-percent alternative rate of return over 100 years, it would be about 8.1 percent.*

acceptable for sawtimber and veneer logs if they meet minimum size and knot specifications (Hiley 1956, Lutz 1958, Marsh 1963).

None of the thinning schedules considered in this study produced less than 6 rings per inch. Only one schedule produced 7 rings per inch, and this only during a 20-year period in a stand on site index 60. On sites less than site index 55, thinning to 90 square feet every 10 years always gave 8 rings or more over the entire range of initial density and stocking considered here. Throughout much of their lives, most red pine stands managed at low densities grow more than 10 rings per inch. Stands managed at higher densities often grew more than 40 rings per inch (Lundgren and Wambach 1963).

On this basis there is little reason to reject the low densities proposed here because of excessive diameter growth. Nevertheless, let's see how great an increase in stumpage price would be needed to overcome any defects in open-grown trees in one of the examples already used.

Suppose timber from the stand shown in figure 11 normally sold for $20 per thousand board feet if thinned back every 10 years to 90 square feet of basal area per acre. If this stand were thinned to 120 square feet, timber would have to sell at $25 per thousand board feet just to equal expectation values from the 90-square-foot density management. Similarly, if thinned to 150 square feet, timber would have to sell at $30 per thousand board feet. Only if stumpage prices differed more than this would we be better off financially to leave a higher density after thinning.

However, if branch size were the problem, low-density stands could be pruned. Suppose that timber from these same stands can be sold for $20 per thousand board feet regardless of whether it comes from pruned stands maintained at 90 square feet or unpruned stands at 150 square feet. The present difference in expectation values is $31 per acre (fig. 11). If this stand is to be thinned to 90 square feet every 10 years, $56 per acre could be spent to prune at age 20 ($56 discounted for 20 years at 3 percent is $31), or $75 per acre to prune at age 30, or some combination of these, and still equal the investment return from managing the stand at 150 square feet of basal area per acre. Or $10 could be spent for release at age 10, $25 for the first pruning at age 20, and $25 to complete pruning at age 30, and still 90 square feet would give as high returns as 150 square feet. If pruned trees of large diameters command a higher stumpage price than unpruned trees of small diameters as one might expect, then even more could be spent on timber stand improvement.

By maintaining red pine at a low density, more can be invested in the stand to improve tree quality. The amount will, of course, vary with the site, stand condition, discount rate, and all the other variables that affect investment return.

Low-density management has the additional advantage of providing more investment flexibility. Trees grown at a low stand density can be sold at an earlier age for larger sized products. On site index 60, with 1,200 trees and 150 square feet of basal area at age 25, for example, the first sawtimber thinnings can be made at age 55 if the stand is thinned to 90 square feet every 10 years, but the first sawtimber cut is delayed until age 65 if thinned to 120 square feet, and until age 75 if thinned to 150 square feet.

Summary

From these examples, which are typical of thousands of others computed for this study, it is evident that leaving 90 square feet of basal area per acre when thinning red pine gives higher investment returns over a wide range of stand conditions, past histories of thinning, costs, prices, and discount rates than does leaving any higher basal area.

The only exception is in growing cordwood if discount rates and establishment costs are low and if larger-diameter trees do not command a higher stumpage price. Even here, however, thinning to 90 square feet gives an investment return near the maximum.

Because it creates a more flexible stand, one that under almost any foreseeable cost and market conditions will earn a higher return or at least as high a return on invested capital as a stand maintained at a greater density, thinning to 90 square feet is a good choice.

Basal Area Densities Lower Than 90 Square Feet

Information on red pine growth at densities below 90 square feet of basal area is available, but most of it is for natural stands with large numbers of trees per acre. These lower densities are not included in this paper because we are not sure how well the data fit stands with fewer trees per acre or where they are no longer reliable.

Thus with all this analysis some important questions remain unanswered. We can conclude from our analysis only that leaving *more* than 90 square feet of basal area per acre after thinning is seldom more profitable than leaving 90 square feet, the lowest density studied. So the field of choice has been greatly limited. But densities of less than 90 square feet may be even more profitable. Obviously much more needs to be learned about low-density management, particularly at low stocking levels. Until this information is available, however, we can thin stands to 90 square feet under most conditions, knowing that this will give a higher return on investment than any higher density.

Financial Rotation Age

At any time during the life of a red pine stand the rotation can be ended by clearcutting, rather than prolonged by thinning. To earn the highest investment return, the rotation should be ended when the capital invested in the land and the timber left after thinning will no longer earn the alternative rate over the next 10-year thinning interval. At this age (the financial rotation age) the stand is financially mature (fig. 14).

Estimation of Financial Rotation Age

At each thinning the rate expected to be earned over the next 10 years by the capital in land and timber left after thinning can be estimated by the following formula:

$$(1+r)^{10} = \frac{FV + LEV}{PV + LEV}$$

where r = the annual rate of value increase

FV is the future value in 10 years of the timber left after thinning

PV is the present value of the timber left

LEV is the land expectation value for growing future timber crops.[8]

Once $(1+r)^{10}$ is calculated, the annual rate of increase (r) can be obtained from interest rate tables, from the log-log scales on a slide rule, or from curved values of $(1+r)^{10}$ plotted for known interest rates (as in fig. 15).

If the expected rate of value growth after thinning (r) is higher than the rate of interest that could be earned in other investments, then the stand is thinned rather than clearcut. If the rate of

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FIGURE 14. — This 95-year-old red pine stand may still be growing in value 5 percent or more each year. When its earning rate falls below what could be earned in other investments, the stand will be financially mature and should be cut.

[8] *The LEV for the appropriate discount rate (alternative rate of return) is included to account for the cost of postponing income from future timber-growing investments on the land.*

value growth is expected to be less than could be earned elsewhere, then the stand is clearcut and the capital is invested elsewhere at the alternative rate. Figure 16 shows the value increase for a typical stand on site index 60 for alternative discount rates. The rate of increase varies with the discount rate used, because the value of the land for growing future crops of timber (the LEV) varies with the discount rate.

With a 4-percent rate as an example, at age 75 the value of the land and timber left after thinning to 90 square feet of basal area per acre is expected to increase at a compound interest rate of 5 percent annually over the next 10 years, so the stand is thinned to 90 square feet. At age 85, when the stand is examined again, it would be expected to increase over the next 10 years at slightly more than 4 percent annually, so the stand is once again thinned to 90 square feet. At age 95 the stand is expected to increase at about 3½ percent, considerably less than the 4 percent that could be earned in other investments, so the entire stand is clearcut because it is financially mature. In this stand the financial rotation is 95 years.

The financial rotation set in this way is also the one giving the highest LEV where conditions remain the same throughout the rotation.

Factors Affecting Financial Rotations

Site, initial stand conditions, stand age, and density left after thinning all affect the rate of volume growth in stands. Within these biological limits, present and future prices and the cost of establishing future stands determine the value growth. All of these factors, together with the alternative rate of return, affect the age at which a stand is financially mature, as the following tabulation shows.

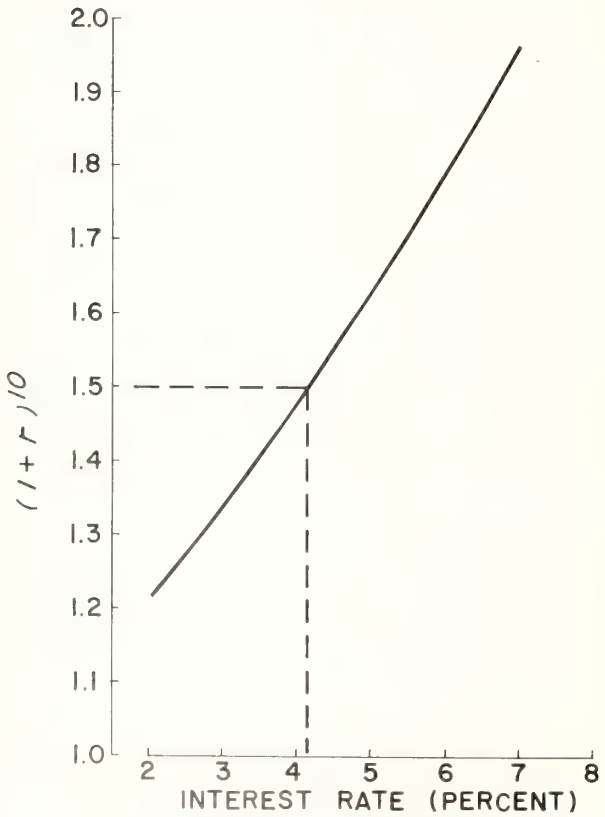

FIGURE 15. — Interest rates for known $(1+r)^{10}$. For example, the interest rate (r) for $(1+r)^{10} = 1.50$ is 4.13 percent.

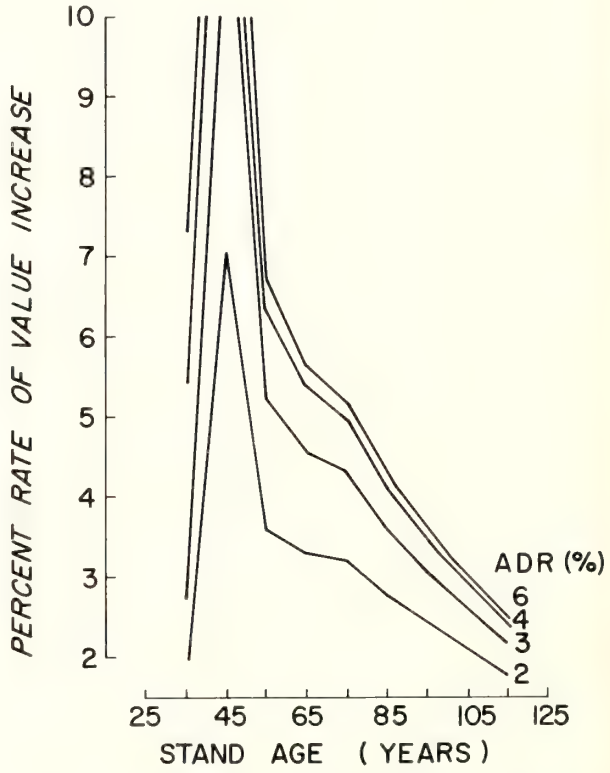

FIGURE 16. — Annual rate of value increase during the next 10 years in a red pine stand on site index 60 for alternative discount rates (ADR). Stumpage prices $20 per thousand board feet and $2 per cord, future establishment costs $40 per acre, 800 trees and 90 square feet of basal area per acre at age 25, thinned every 10 years to 90 square feet.

Varying factor (all others constant)	*Rotations may be shorter if level is—*	*Rotations may be longer if level is—*
Site index	Low	High
Initial stocking (no. of trees)	Low	High
Initial density (basal area)	High	Low
Density after thinning	High	Low
Future establishment costs	Low	High
Stumpage prices	High	Low
Alternative rates	High	Low

Except for discount rates, no single factor greatly affects rotation ages. A large difference in site or future establishment costs, for example, changes the rotation by only 10 or 20 years. However, the cumulative effect from a number of factors can be large.

Let us consider a red pine stand on site index 45, with 800 trees and 120 square feet of basal area per acre before thinning at age 25, to be thinned every 10 years to 120 square feet of basal area, with no cost of establishment, $3 per cord stumpage price, and an 8-percent alternative rate of return. This stand has an LEV of $5.30 per acre, and a financial rotation age of 25 years, the shortest rotation considered. To get the highest return on invested capital, this stand should be cut as soon as it is merchantable for cordwood.

In contrast, red pine on site index 60, with 1,600 trees and 90 square feet of basal area per acre at age 25, thinned every 10 years to 90 square feet of basal area per acre, with $80 per acre cost of establishment, $10 per thousand board feet and $1 per cord stumpage price, and a 2-percent alternative rate of return, has an LEV of --$5.60 per acre and a financial rotation age of 155 years.

Financial rotations of these two stands differ by 130 years; yet the stand conditions do not include the extremes that may be found. Neither do the costs, prices, and alternative rates of return cover the entire range that may be expected. Because financial rotations vary widely among red pine stands the same rotation should not be used for all red pine stands if the goal is to earn a high return on invested capital. Although rotation ages do vary among stands, it is also true that in any one stand under a given set of costs and prices, rotations can vary somewhat from the financial rotation age and not greatly affect estimates of LEV's. This fact can be put to good use in evaluating investment alternatives.

A good illustration of this is given by a red pine stand established on site-index-50 land at $40 per acre (fig. 17). This stand is expected to have 800 trees and 120 square feet of basal area per acre at age 25. It is to be thinned every 10 years to 90 square feet of basal area per acre with cordwood and sawtimber sold at $2 per cord and $20 per thousand board feet. The discount rate is 3 percent. Here, rotations of 25, 35, and 45 years give negative LEV's (indicating that rotations this short will not earn 3 percent on invested capital). As the rotation is lengthened, the values increase to a maximum at age 85, the financial rotation. If the rotation is extended beyond 85 years, the LEV decreases slowly but steadily.

Note that the LEV's do not vary greatly over a range of rotations. As the following tabulation shows, the LEV's lie between $47 and $50 per acre for rotation ages from 75 to 115 years.

Rotation age	*LEV*	*Percent below maximum*
65	$40.99	17.9
75	47.16	5.6
85	49.94	0.0
95	49.88	0.1
105	48.59	2.7
115	46.89	6.1
125	44.98	9.9

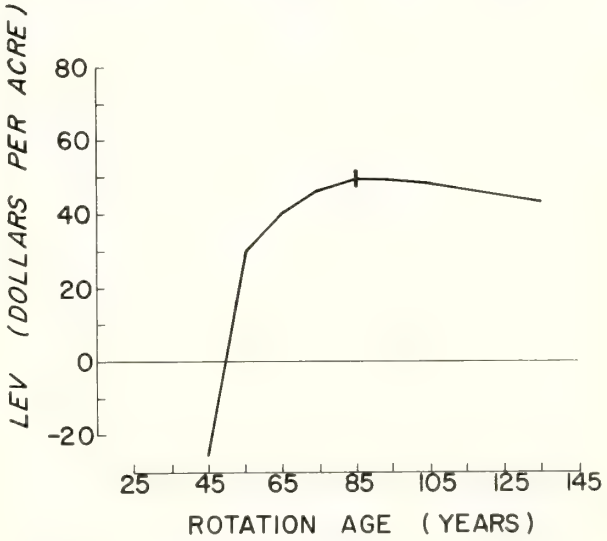

FIGURE 17. — Red pine land expectation values (LEV) vary with rotation age. Site index 50, thinned every 10 years to 90 square feet, establishment costs $40 per acre, stumpage prices $20 per thousand board feet and $2 per cord, discount rate 3 percent, 800 trees and 120 square feet at age 25.

In valuing this investment the financial rotation, 85 years, should be used; but any rotation between 75 and 115 years will give an LEV within 6 percent of the highest obtainable.

Most thinned stands of red pine follow the same general pattern: negative or low expectation values for short rotations, followed by a rapid increase to a maximum, and then a gradual decline as rotations lengthen. Under many conditions, setting the rotation within 10 or 20 years on either side of the financial rotation age will not greatly affect estimates of investment returns. Thus, it may be possible to use a common rotation age in estimating LEV's for specified situations.

For example, financial rotations in the stands in figure 18 vary from 85 years on site index 45 to 95 years on site index 60. A rotation age of either 85 or 95 years could be used for all sites, and the estimated LEV would be within 2 percent of the maximum for any site within this range, as the following tabulation shows.

Site index	*LEV for rotation age —*	
	85	*95*
45	$32.00	$31.50
50	52.10	52.00
55	74.50	75.50
60	105.10	105.90

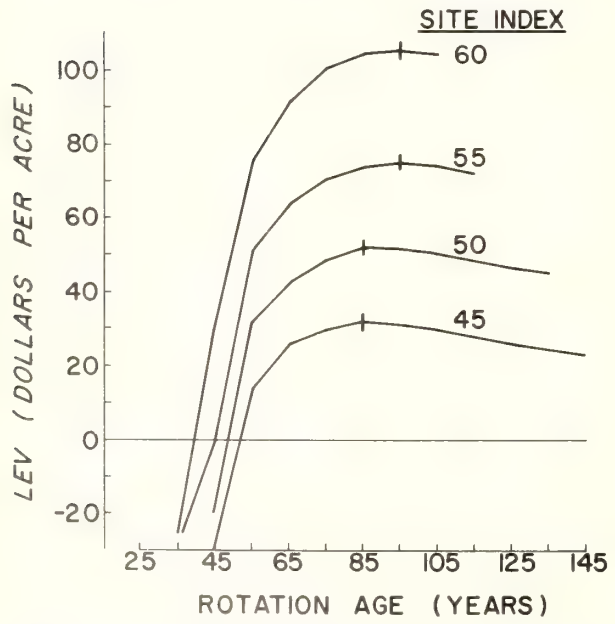

FIGURE 18. — Financial rotations in red pine stands vary with sites. Thinned every 10 years to 90 square feet, establishment costs $40 per acre, stumpage prices $20 per thousand board feet and $2 per cord, discount rate 3 percent, 800 trees and varying basal areas at age 25. LEV is land expectation value.

If stands differ in only one or two respects, a common rotation age often can be used without much error in estimating investment returns. However, if stands differ greatly in many respects, a common rotation age should be used with caution or LEV estimates may be seriously in error.

Some Suggested Financial Rotation Ages

In red pine stands grown for sale only as cordwood at constant prices and thinned every 10 years to 90 square feet, initial stand conditions have almost no effect on financial rotations and can be ignored. Cordwood volume growth is not affected by tree diameter, only by age, site, and basal area left after thinning. If all stands are thinned to 90 square feet every 10 years, as recommended, then at any given stand age the cordwood volume growth depends only upon site; and the value growth depends upon site, prices, and costs.

With a $4-per-cord stumpage price most red pine stands will have the financial rotations shown in table 1 for given sites and regeneration costs. Few will have rotations that differ from these by more than 10 years.

As this table illustrates, financial rotations are longer at lower interest rates. Higher regeneration costs also lengthen rotations, because longer rotations postpone these costs. At a stumpage price of $4 per cord, stands with regeneration costs of $40 or more will usually have a negative LEV for interest rates of 4 percent or higher, indicating that at these costs and prices the stands cannot earn this rate on invested capital. The rotations shown here are those that will maximize returns or minimize losses if stands with a negative LEV are regenerated under these conditions. If stands with a negative LEV are not to be regenerated, they will have the rotations shown in parentheses.

The rotations shown here also apply for constant stumpage prices other than $4 per cord if the regeneration cost intervals are adjusted. The $0, $40, and $80 regeneration costs for which rotations are given represent the value of 0, 10, and 20 cords respectively. For example, at a stumpage price of $2.50 per cord, the rotations shown apply for regeneration costs of $0, $25, and $50. The footnotes to the table suggest how rotation ages can be adjusted to the other changes in conditions.

Although this table is not a perfect substitute for a complete evaluation of financial maturity in

TABLE 1. — *Financial rotation ages in thinned red pine stands for all initial stand conditions.*[1] *Only cordwood sold.*[2]

Site index	Future regeneration costs per acre	Interest rate (percent)			
		2	4	6	8
	Dollars	*Years*	*Years*	*Years*	*Years*
45	0	65	45	35	35
	40	85	75(65)	65(45)	55(35)
	80	105	105(65)	95(45)	85(35)
60	0	75	55	45	35
	40	95	85(75)	65(55)	55(35)
	80	105	105(75)	95(55)	85(35)

NOTE: These rotations assume that the land will be used to grow a new crop of timber even if the LEV is negative. Rotations in parentheses assume that no new crop will be established because the LEV is negative.

1 *Thinned every 10 years to 90 square feet of basal area per acre, 400 to 1,600 trees and 90 square feet of basal area per acre before thinning at age 25. Stands with only 60 square feet of basal area at age 25 would have rotations longer by about 10 years.*

2 *Stumpage price $4 per cord. If stumpage prices increase with tree size, rotations will be longer.*

TABLE 2. — *Financial rotation ages in thinned red pine stands.*[1] *Sawtimber and cordwood sold*[2]

Site index	Age 25		Interest rate (percent)			
	Trees[3] per acre	Average d.b.h.	2	4	6	8
	Number	*Inches*	*Years*	*Years*	*Years*	*Years*
45	400	6.4	85	75	65	55
	800	4.5	95	85	75	65
	1,200	3.7	105	95	85	75
	1,600	3.2	115	105	95	85
60	400	6.4	95	85	65	45
	800	4.5	115	95	75	55
	1,200	3.7	125	105	85	65
	1,600	3.2	135	115	95	75

1 *Thinned every 10 years to 90 square feet of basal area per acre.*

2 *Stumpage price $20 per thousand board feet and $2 per cord, and regeneration costs of $20 to $80 per acre. Regeneration costs below $20 per acre will shorten rotations by about 10 years.*

3 *Number of trees per acre at age 25 after thinning to 90 square feet of basal area per acre.*

each stand at each thinning age, financial rotations determined by a detailed appraisal are not likely to differ from those shown here by more than 10 years.

In sawtimber stands, the rate of board-foot volume growth after thinning to 90 square feet is affected not only by site and age, but also by average stand diameters. Tree diameters determine the board-foot recovery from a given cubic-foot volume. Under the assumptions in this analysis, any stands with the same site index, age, and average stand diameter after being thinned to 90 square feet will have identical cubic-foot, cordwood, and board-foot standing volumes and volume growth over the next 10 years. If costs and prices also are the same, then so will be the value growth and the financial rotation (table 2).

Figure 19 shows the average diameters expected at each age in stands with the initial conditions given in table 2 if the stands are thinned every 10 years to 90 square feet. If the site, age, and average stand diameter are known for any older stand, one can use figure 19 to determine what initial conditions would have produced this kind of stand. In this way any stand, regardless of its past history, can be described by the average diameter (or number of trees with 90 square feet of basal area) at age 25 of a stand that has followed the prescribed thinning pattern.

For example, a 75-year-old stand on site index 60 with an average diameter of 13 inches has the same diameter as a stand that started out with slightly more than 800 trees per acre and 90 square feet at age 25. Such a stand will have financial rotations of about 115, 95, 75, and 55 years for discount rates of 2, 4, 6, and 8 percent (table 2), assuming the sawtimber stumpage prices and costs are within the range of the table.

Financial rotations are longer in stands grown for both sawtimber and cordwood than in stands grown only for cordwood (compare table 2 with table 1). This comes as no surprise. Once a stand is merchantable for sawtimber, at any given age the board-foot volume growth rate is higher than the cordwood volume growth rate, because not only does the cubic-foot volume increase but also the ratio of board feet to cubic feet.

Although these rotations are for a constant stumpage price of $20 per thousand board feet and $2 per cord over a range of regeneration costs from $20 to $80, these same rotations apply to other constant stumpage prices with a range of regeneration costs equal to the value of from 1 to 4 thousand board feet. For example, at $30 per thousand board feet and $3 per cord they apply for regeneration costs from $30 to $120 per acre; at $10 per thousand board feet and $1 per cord, for costs from $10 to $40 per acre. The ratio of sawtimber prices to cordwood prices can vary widely without much effect on rotations.

Price increases over time, whether from a change in stand characteristics or an increase in price levels, will tend to lengthen rotation ages. In one of the markets evaluated, prices rose $1 per thousand board feet for every inch increase in diameter. Table 3 shows financial rotations for this market. However, even such a sizable price increase, which often amounted to $2 or more per thousand board feet every 10 years, seldom lengthened rotation ages by more than 10 years (compare table 3 with table 2).

If stumpage prices are expected to increase at some given rate over time, financial rotations should be adjusted to reflect this fact. This can be done by subtracting the annual percent rate of price increase from the discount rate used (the

TABLE 3. — *Financial rotation ages in thinned red pine stands.*[1] *Sawtimber and cordwood sold at prices increasing with average stand diameter*[2]

Site index	Age 25		Interest rate (percent)			
	Trees[3] per acre	Average d.b.h.	2	4	6	8
	Number	*Inches*	*Years*	*Years*	*Years*	*Years*
45	400	6.4	105	85	75	55
	800	4.5	115	95	75	65
	1,200	3.7	115	95	85	75
	1,600	3.2	125	105	95	85
60	400	6.4	95	95	75	65
	800	4.5	115	105	85	75
	1,200	3.7	145	115	95	75
	1,600	3.2	165	125	105	85

[1] *Thinned every 10 years to 90 square feet of basal area per acre.*

[2] *Stumpage prices $(DBH + 5)$ per thousand board feet, $(\frac{1}{2}DBH - 1)$ per cord.*

[3] *Number of trees per acre at age 25 after thinning to 90 square feet of basal area per acre.*

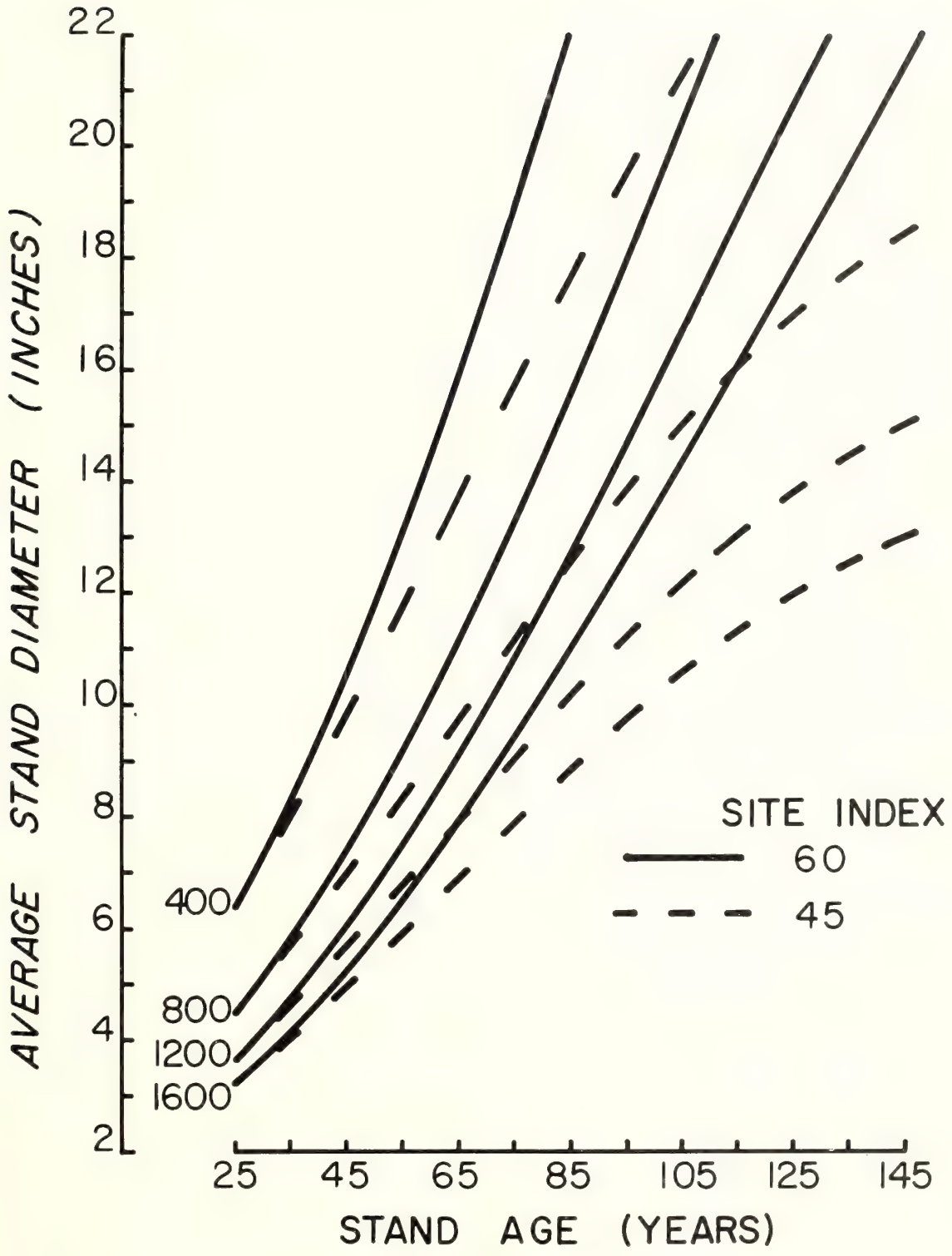

FIGURE 19. — Average diameters of red pine stands thinned to 90 square feet of basal area per acre at age 25 and every 10 years thereafter; for stands on site index 45 and 60, and with from 400 to 1,600 trees per acre after thinning at age 25.

alternative rate) to get an adjusted discount rate. If prices are expected to increase at 2 percent annually and the alternative discount rate is 6 percent, 4 percent should be used as the adjusted discount rate for estimating financial rotations. The slight error in this approximation will have little effect on rotations.

As noted before, these tables do not replace a more detailed examination and projection of yields and prices for determining financial maturity. But a more detailed evaluation is not likely to change these rotations by more than 10 years, and the practical effect on investment returns will usually be small.

A Final Word

The aim of this paper was to explain how rotation ages and stand density left after thinning — two factors that the forest manager can control — affect investment returns from growing red pine.[9] It has demonstrated that red pine stands thinned every 10 years to 90 square feet of basal area per acre will earn a higher return on invested capital than will stands thinned to a higher density. It has suggested financial rotations for red pine grown only for cordwood and for red pine grown for sawtimber and cordwood jointly.

All of the examples and conclusions given in this paper are based on growth and yield data developed from many research plots in pure stands of red pine in northern Minnesota. The stands evaluated here are constructed from these growth and yield data. They are not actual stands. Because these data are averages they will not necessarily apply to any one single stand over a particular period of time, but are what can be expected from several similar stands over a long time. Although these data are confined to northern Minnesota and do not include the better quality sites, the same general conclusions are likely to hold over the entire range of red pine. Similar recommendations for low-density management are being made for other pine species throughout the world.[10]

It was not possible to consider all of the special products such as posts, poles, piling, and mine timbers that can be produced in red pine stands. Any management recommendations made here apply only under the markets evaluated. A forester with special markets must decide for himself how he can adjust his thinning practices or rotation age to produce these special products efficiently and earn a high return on his invested capital. In doing this he can use some of the principles brought out here. For example, if he thinks he must keep a density higher than 90 square feet to grow high-quality poles, then the stumpage price per pole must be high enough to offset the loss in income from a lower volume of thinnings and the slower future growth of sawtimber trees.

In covering a broad range of problems and conditions we have had to be brief. Many questions have been left only partially answered, and some may not have been answered at all. However, this paper does give the forest manager some of the information needed to manage red pine stands efficiently. Although this study may not have found the pattern of basal area density left after thinning that will give the highest possible return on invested capital, it suggests a thinning schedule that clearly is better than a wide range of alternative schedules.

The 90-square-foot basal area density recommended here does not conflict with the density range of 90 to 110 square feet recommended by the U.S. Forest Service (1965) timber management guide for the red pine type in the North Central Region. The conclusions from this study suggest, however, that if red pine is to be grown for saw logs or veneer logs, no more than 90 square feet of basal area per acre should be left after thinning if capital invested in growing red pine is to be used most efficiently.

Most of the sawtimber rotations suggested here are shorter than the 120 to 140 years recommended by the timber management guide for the red pine type. However, the present older stands of red

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[9] *A later paper will show how to calculate investment returns for specific red pine timber-growing opportunities, and how to use present values and rates of return to compare investment alternatives and answer questions about timber-growing investments.*

[10] *For example, see Hiley (1958) on South African pine plantations, Wiksten (1960) and Andersson (1963) on Scots pine (Pinus sylvestris L.) in Sweden, and Lewis (1962) on Pinus radiata (D. Don) stands in Australia.*

pine to which these rotation ages refer undoubtedly were densely stocked throughout most of their life. They have been thinned only during the last few decades. As tables 2 and 3 show, densely stocked stands on medium sites (50 to 60) do have financial rotations this long if alternative rates are low. On medium sites, such stands are still increasing in value at about 3 percent a year at age 120, and 2 percent at age 140. Furthermore, these long rotations may be desirable to maintain sawtimber production from the small acreage of these older stands until they can be replaced by plantations old enough to produce sawtimber. Rotations this long are not likely to be used in the more lightly stocked plantations, because the earning rate would be even lower in plantations this old.

Earning a high return on invested capital is not the only objective of timber management, but it is an important one. Although other objectives may be given a higher priority at some places and at some times, it is difficult to justify a plan of management that accepts an investment return lower than could be obtained by some other plan unless the added benefits clearly outweigh the loss in income and increased timber production costs.

Throughout the discussion we have tried to show how to get the highest investment return from individual red pine stands. This is only a first step towards getting the highest investment return from all timber-growing activities in an organization; but it is a necessary step. Unless the costs and returns from growing timber in each stand are evaluated, we are in a poor position to evaluate an entire forest property. Until more information on other forest types is available over a wider range of sites and stand densities, at least it is possible to manage red pine stands to insure high investment returns.

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U.S. FOREST SERVICE
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CHARACTERISTICS of FAMILY CAMPERS USING THE HURON-MANISTEE NATIONAL FORESTS

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U. S. DEPARTMENT OF AGRICULTURE

CONTENTS

	Page
INTRODUCTION	1
CONCLUSIONS	1
METHODS	2
FINDINGS	3
The Markets	3
Campground Use	3
Characteristics of Campers	4
MANAGEMENT IMPLICATIONS	10
Campground Development	10
Visitor Information Programs	10
Public Relations	10
A FINAL REMARK	11
LITERATURE CITED	11

Characteristics of Family Campers Using the Huron-Manistee National Forests

by David A. King

INTRODUCTION

During the summer of 1962, a study was made of camping families using the Huron-Manistee National Forests in Lower Michigan. Both the socioeconomic characteristics and campground use of the families were measured. The objectives of the study were: first, to describe the camping families and determine if differences existed with respect to these between the Forests, and second, to identify the variables related to campsite use. Only the first topic is discussed here. The second part of the study — the relation of the variables to campsite use — will be presented elsewhere.

As shown in the last section of this paper, the findings on the characteristics of the campers have important implications for three recreation management problems: campground development, visitor information services, and public relations.

CONCLUSIONS

1. The study, based on a sample of family campers using the Huron-Manistee National Forests in Lower Michigan, showed the campsite market areas to be small and oriented to the south. News releases intended for campers need not be sent beyond an area bounded on the south by a line between Chicago and Cleveland and on the north by the Straits of Mackinac. The orientation of the market indicates that campground development in the southern portions of the Forests would increase accessibility.

2. The Forests provide weekend and short vacation camping. About 80 percent of the families took only one trip to the Forests during the season, and the camping trips averaged 5 days in length. The apparent high turnover in families throughout the season indicates that variety in Visitor Information Service (VIS) programs between days, but not between weeks, is sufficient.

NOTE: The author is an Associate Economist at the Lake States Forest Experiment Station, which is maintained at St. Paul, Minn. by the Forest Service, U.S. Department of Agriculture, in cooperation with the University of Minnesota. *The author wishes to acknowledge the helpful advice and counsel of Dr. Richard A. Skok, University of Minnesota.*

3. The income, occupation, and education data show that these families are in the middle and upper-middle classes and suggest the need for a high-quality VIS program. Probably the families are also above average in awareness of natural resource management controversy and often have questions about resource policy that deserve good logical answers. Efforts to provide answers are worthwhile because the campers represent the politically more expressive socioeconomic classes in the general population.

4. Family groups and families with children were the predominant users of the campsites. Campground facilities that offer opportunities for a variety of activities are needed. The mixture of children and adults creates a problem in VIS presentations. Daytime presentations for children and their parents and night presentations for adults are suggested.

5. The families were generally experienced campers, but few of them had camped on these Forests. They probably gained their experience in State Parks. Therefore, there may be a need to inform and educate them about management of forest land for objectives other than recreation.

METHODS

The Huron-Manistee National Forests (fig. 1) are close to the major population centers of the Manufacturing Belt. The Manistee is more accessible to the Chicago area than is the Huron, but both are about equally accessible to the Detroit area. Their major recreation attraction is the general forest and water environment, which is fairly uniform over both Forests. The Manistee is traversed by more rivers than the Huron; but the well known Au Sable River runs the length of the Huron.

The two Forests were sampled independently so that comparisons could be made. The study period extended from April 28 through September 14, 1962. This included all of the trout season and all of the school summer vacation period.

All of the campgrounds on both Forests were sampled, each one on 24 days. The sample days were spread throughout the study period to include possible seasonal influences.

Each time a campground was sampled, 25 percent of the occupied campsites were selected at random, and the family or group occupying each of these sites was interviewed. At least one campsite was sampled if the campground was occupied at all. In total, 564 groups were interviewed.

This method of sampling has a built-in bias. The probability that a family is in the sample is a function of the number of days they spent camping on the Forest during the study period. Thus, families who camped a large number of days are overrepresented relative to those who camped for fewer days. A completely satisfactory method of avoiding

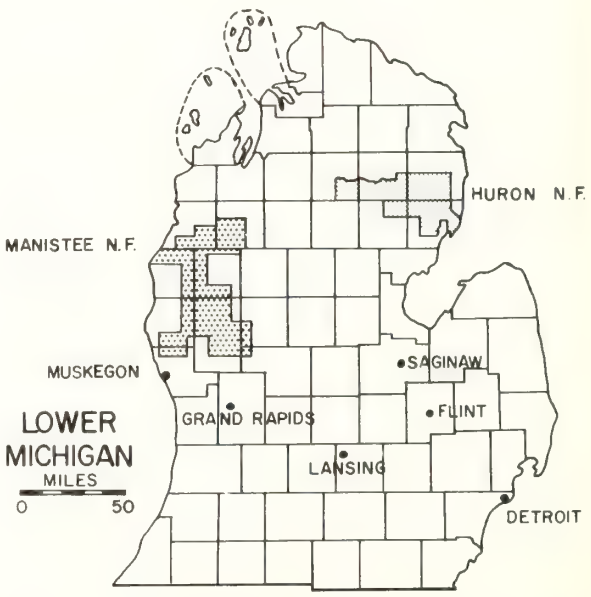

FIGURE 1. — Location of the Huron and Manistee National Forests.

this bias in sample selection has not been developed, but a correction for the bias, as suggested by Lucas (1963), was made in the data analysis.

Another possible source of bias in the data stems from the sampling of both family and nonfamily groups. However, over 87 percent of the groups interviewed were family groups, and only these data are reported here.

Still another possible source of bias results from the method of measuring total days of camping during the study period. The interviewer obtained information on days camped on previous trips to the Forests, but a return postcard was used to obtain the families' camping use of the Forests after the trip on which they were interviewed. The requested information on total days camped for the study period was obtained for 80 percent of the camping families sampled. Tests were made of differences between respondents and nonrespondents with respect to the distributions of the major variables. The only statistically significant difference (at the 5-percent level) was found for the distributions of the number of years the family had camped on the Forests, and this difference existed only for the Huron sample. The analysis was made on the assumption of no difference between respondents and nonrespondents.[1] The final sample size for which complete data were obtained was 395 families, 178 for the Huron and 217 for the Manistee.

Personal interviews, with an interviewer asking questions and recording answers, were used to gather the data. In general, respondent attitude toward the study and the interviewer was very receptive. None refused to be interviewed and only three families refused to answer specific questions — those referring to income and assets.

FINDINGS

The Markets

The Forests' campsite markets do not cover large areas (figs. 2 and 3), but do include 10 percent of the nation's population. The Manistee sample included four families and the Huron sample eight families from outside the North Central Census Region, less than 3 percent of all families in the samples. About 85 percent of the families came from Michigan and about 90 percent lived within a day's drive of the Forests (fig. 4).

Generally, the further a county is from the Forests the lower is the probability that a family living in that county camped on the Forests (King, 1965). It is interesting to note, however, that none of the family campers came from north of the Straits of Mackinac, and only two families lived in a county north of either of the Forests. This probably is a result of much lower population and income levels, combined with greater recreation opportunity, in counties to the north. It may also illustrate the lure of the North for the residents of the North Central Region — vacationing, sightseeing, and fishing are believed to be better "up North."

Campground Use

Approximately 80 percent of the families took only one camping trip to the Forests, and most of them visited the Forests for only a short time (tables 1 and 2). The averages per family were as follows:

	Huron	*Manistee*
Mean days camped per season	6.3	6.2
Median days camped per season	4.1	4.0
Mean days camped per trip	5.0	4.7
Mean trips per season	1.3	1.4

Since the mean length of trip was longer than a weekend but less than a week, one might conclude that the trips taken included other destinations. However, approximately 83 percent of the families gave the Forest as the primary objective of the trip during which they were interviewed.

[1] *More details on the sampling procedure are available in mimeographed form upon request to the Station.*

TABLE 1. — *Number of camping trips taken to Forests, per family (In percent)*

Number of trips	Huron	Manistee	Total
1	82	78	80
2	12	13	12
3	4	6	5
4	1	2	2
5 and more[1]	1	1	1

[1] *Maximum was 10 for the Huron and 14 for the Manistee.*

TABLE 2. — *Total days camped per family during study period (In percent)*

Days[1]	Huron n=178	Manistee n=217	Total
2	17	15	15
3	22	23	23
4	10	12	11
5	7	8	8
6	7	7	7
7	5	8	7
8	5	6	6
9	7	3	5
10	5	3	4
11	1	3	2
12	1	3	2
13	3	2	2
14	3	1	2
15	1	2	2
16	1	1	1
17	2	1	1
18		1	1
19		(2)	
20-67	3	1	2

[1] *The minimum possible days of camping is two, since any part of a calendar day spent in camping was counted as one day.*

[2] *Less than 0.5 percent.*

The data on average length of trip and frequency of trips indicate that camping on the Forests cannot be clearly labeled as either vacation or weekend camping. To determine if a division between weekend trips and longer trips was being hidden by the means and medians, the percentages of families in three classes of average length of trip were calculated:

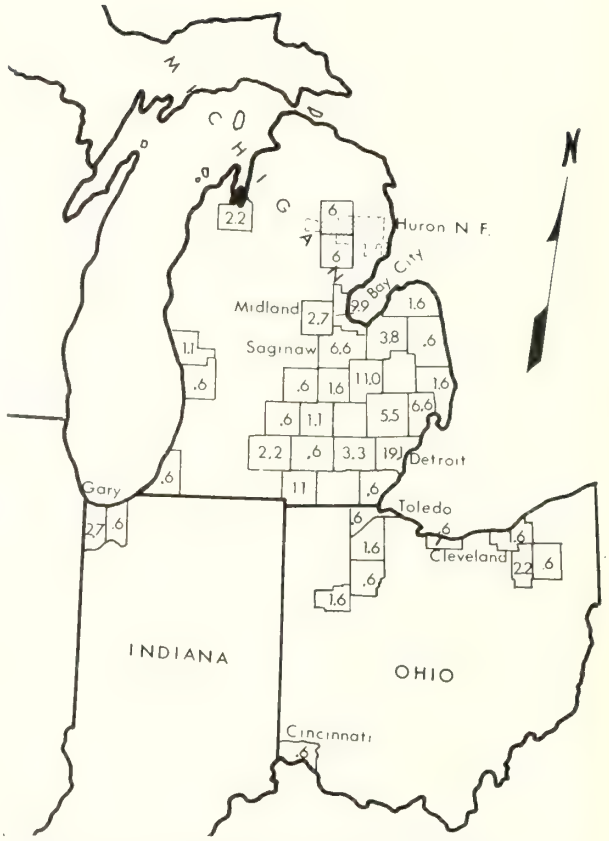

FIGURE 2. — Percent of 1962 Huron National Forest camping families by county of residence.

Trip length (days)	*Huron*	*Manistee*
2-3	45	50
4-9	45	41
10 or more	10	9

If trips longer than 3 days are classified as vacation trips, then camping on the Forests is apparently equally divided between weekend trips and short vacation trips. This division suggests a weekend peakload but a substantial amount of use throughout the week.

Characteristics of Campers

Income. — The family income means and medians indicate that a campground use fee would not be a serious deterrent for these

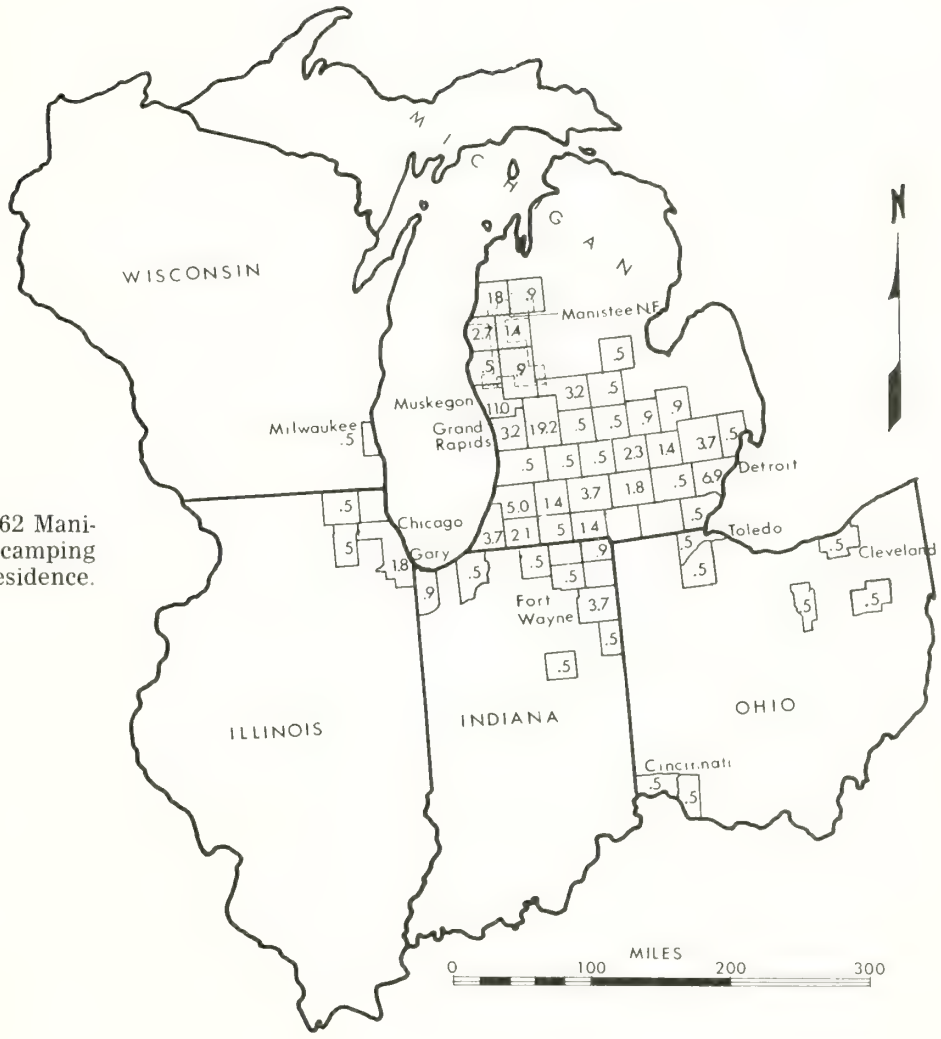

FIGURE 3. — Percent of 1962 Manistee National Forest camping families by county of residence.

families (fig. 5). While there did not seem to be any reason to expect the camper incomes to differ between Forests, they did. The distributions differed significantly at the 1-percent level.[2] The major portion of this difference occurs in the $10,000 and over income classes, in which the Huron had a higher proportion of families than the Manistee. This difference in income distributions between the Forests is primarily the result of differences in the campsite market populations rather than differences in the attractions of the two Forests. A comparison of the income distributions between the two campsite markets showed a significant difference. The higher incomes of the families using the Huron indicate that the potential for camper expenditures in the local economy is higher for the Huron than the Manistee.

Occupation. — The largest proportion of family heads were in the craftsmen and foremen class on both forests (fig. 6).[3] Farmers

[2] *The Kolmogorov-Smirnov test (Siegel, 1956) was used to test differences in the distributions of the quantitative variables. Chi-square was used for tests of the occupation distributions. The 1-percent level of significance was used for all comparisons.*

[3] *The occuption classes used are as defined in the 1960 U.S. Census of Population.*

and farm managers had the lowest representation. The occupation distributions differed significantly between Forests. The main difference is in the manager, official, and proprietor class — more common on the Huron — and the clerical-sales class — more common on the Manistee. These differences agree with those found in the income distributions; the Huron has a higher proportion of family heads in the high-income occupations than the Manistee.

Education. — Two-thirds of the family heads had *at least* a high school education (fig. 7). This is higher than the proportion with that amount of education in the campsite market.

Family structure. — Families averaged about four members and families with children predominate (fig. 8); about 80 percent of the families had children. The relative distribution of children in three age classes is shown below.

Age	*Percent*
1-5	25
6-12	49
13-18	26

Place of residence. — About 80 percent of the families were urban[4] residents. The Census urban definition used is broad and inclusive in terms of population density. A more detailed breakdown might have shown a high proportion of suburban and rural nonfarm residents with a low proportion of rural farm and central city residents. This is partially shown by the low proportion of farm-

[4] *Urban places of residence were identified from the 1960 Census of Population. An urban place is defined in the Census to be "All incorporated and unincorporated places of 2,500 inhabitants or more, and the towns, townships, and counties classified as urban."*

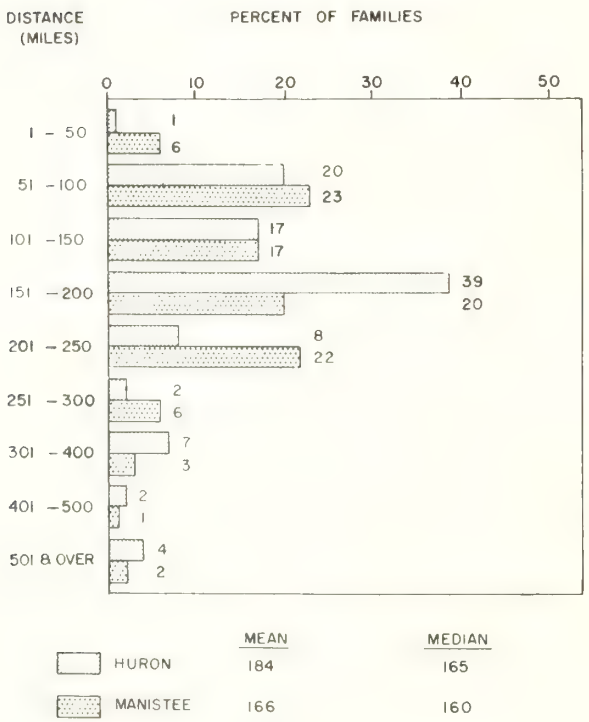

FIGURE 4. — The distances traveled to the Forests by camping families using the Huron and Manistee National Forests, 1962.

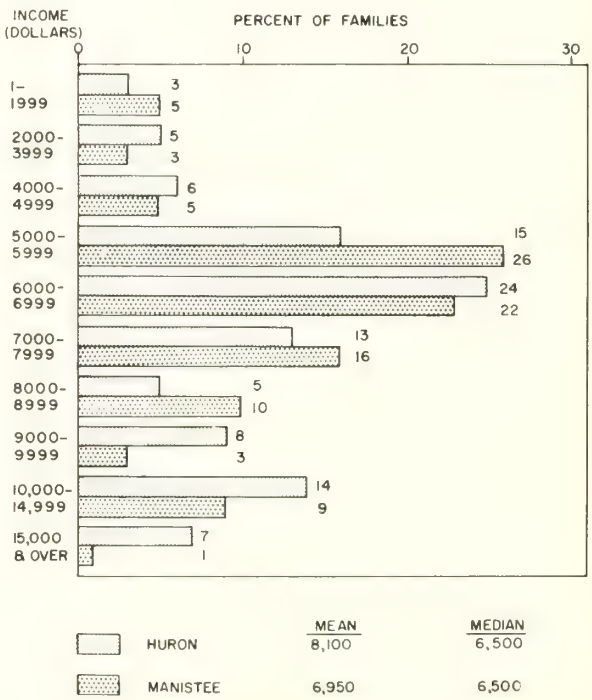

FIGURE 5. — The family incomes of camping families using the Huron and Manistee National Forests in 1962.

ers, 1.5 percent, relative to the proportion of rural residents, 20 percent.

Camping experience. — Two kinds of previous camping experience were measured, years of camping anywhere and years of camping on these Forests. Years may not be the best measure of experience, but are more accurately recalled than total occasions or total days over a lifetime. About half of the families had 10 years or more of camping experience, but about half were in their first year of camping on the Forests (fig. 9). Apparently many campers on the Huron-Manistee are experienced campers who have just recently discovered the Forests. A combination of some increase in campground capacity and publicity may have drawn these people to the Forests. Between 1955 and 1960, 42 family units were added to the Forest campground capacity. Several feature articles about camping on the Forests appeared in the Detroit and Chicago newspapers in 1961. Whether the campers return in future years

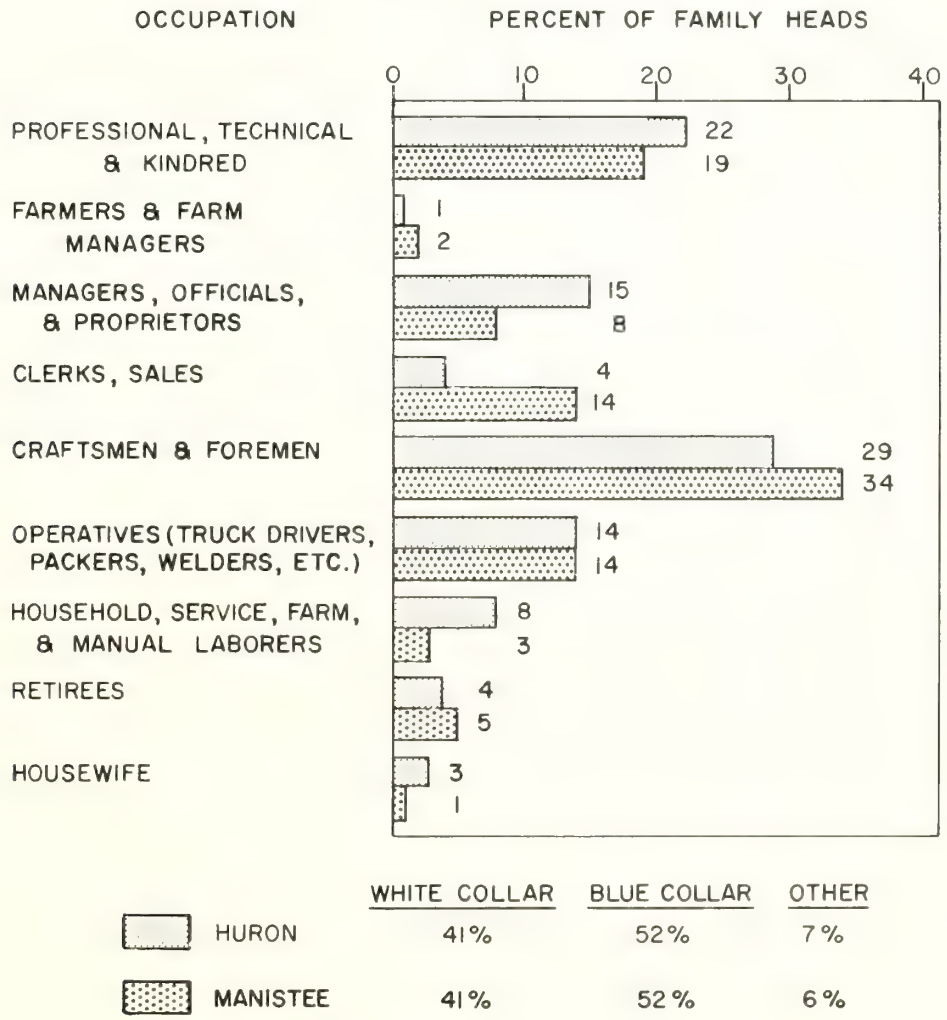

FIGURE 6. — The occupations of heads of camping families using the Huron and Manistee National Forests in 1962.

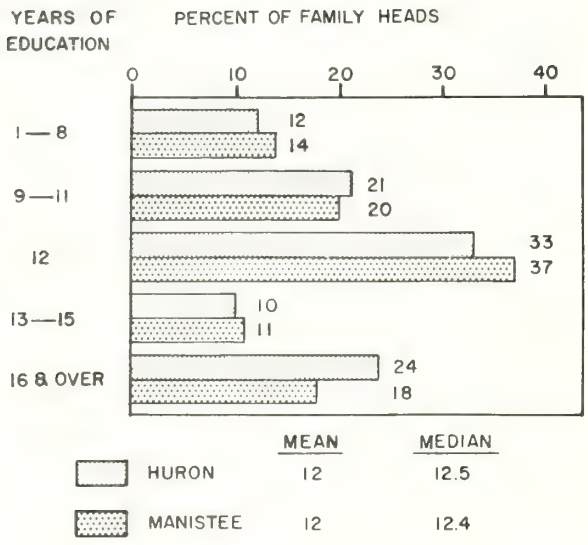

FIGURE 7. — The education of heads of camping families using the Huron and Manistee National Forests in 1962.

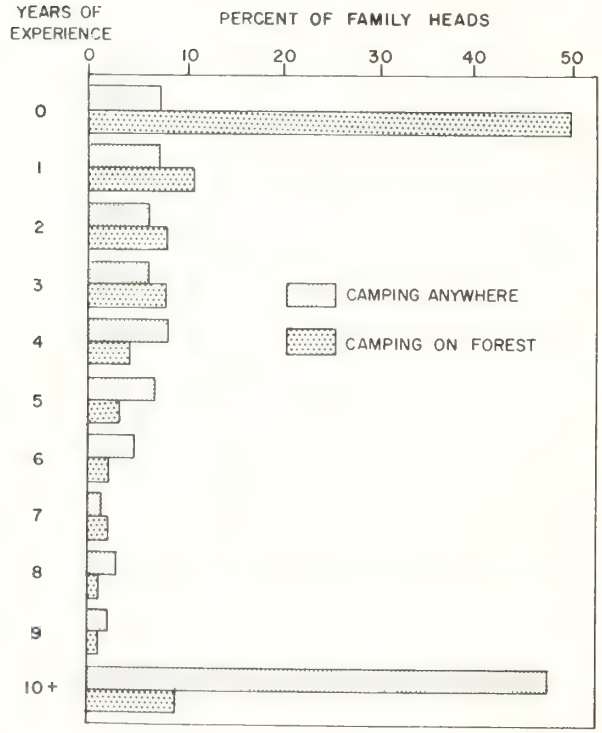

FIGURE 9. — Years of previous camping experience by heads of camping families using the Huron and Manistee National Forests in 1962.

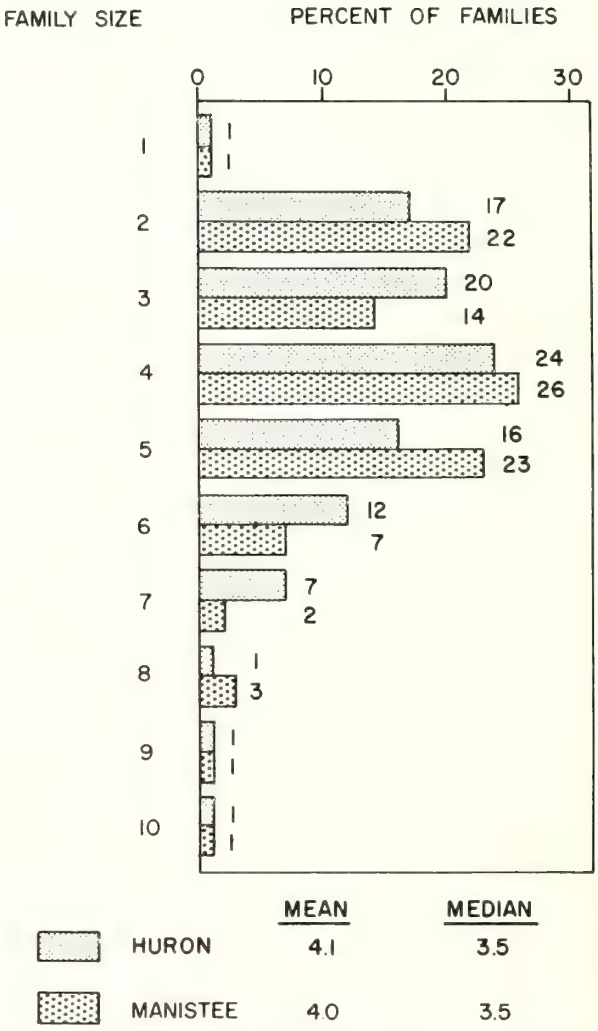

FIGURE 8. — The sizes of camping families using the Huron and Manistee National Forests in 1962. Single persons living alone were counted as one-member families.

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FIGURE 10. — Swimming is one of the favorite activities among family campers, and the most popular campgrounds are those with beaches.

will depend on how well the campgrounds satisfied their desires. If the implied "recruitment" rate remains high and the proportion who continue to camp on the Forests is relatively high, future use could expand rapidly.

Type of shelter. — The tent is the major form of shelter used by these campers. However, as shown in the tabulation below, some type of trailer was used by 41 percent of them and other types of wheeled shelter by an additional 2 or 3 percent of the families.

Type of shelter	*Percent*
Tents	56
House trailer	30
Tent trailer	11
Pick-up camper	1
Station wagon	1
Other[1]	1

[1] *Includes sleeping in the open and in converted buses.*

MANAGEMENT IMPLICATIONS

Campground Development

The small size of the markets and their orientation to the south indicate clearly that campground development in southern portions of the Forests would increase accessibility. However, campgrounds further north may be more attractive because they are farther "up North."

A problem in campground design may intensify if the proportion of campers (30 percent) using house trailers increases in the future. A turn-out campsite spur is more easily used by a trailer camper than a back-in spur, but is also more expensive to construct and less pleasing esthetically.

The high proportion of families with children shows the need for facilities, in or near campgrounds, that will serve the variety of interests found within such families. Some examples are swimming facilities, nature trails, boat rentals, and auto sightseeing tours. Among these, swimming is particularly appealing to families with children (fig. 10). A lake campground with a beach tends to be over-used because of the popularity of swimming. Wherever opportunities exist, investment in the development of beaches at lake campgrounds should be given high priority.

Visitor Information Programs

Variety in information programs from day to day, but not between weeks, would appear to be adequate. This is suggested by the low frequency of trips per family and the average length of trip — 5 days. Evidently there is a high turnover of families, and they tend to stay less than a week.

The predominance of families with children raises a VIS (Visitor Information Service) problem — how to present information to hold the interest of both children and adults, especially when three-fourths of the children are of preschool and elementary school age. The opportunity to inform the adults is not fully met by pitching all programs at a child's level of understanding. A solution might be the use of daytime presentations for children with parents and night presentations for adults.

A number of factors shows the need for a high-quality VIS program. The education and camping experience data indicate that these families have the capacity and interest to understand fairly sophisticated presentations of information. Although they are generally experienced campers, much of this experience has been gained elsewhere than on these Forests — probably in State Parks. Thus, they may have had little exposure to information on wild land management for purposes other than recreation. Casual observation indicated that the campers are interested in the management of public wild lands, but are confused by the many different State and federal agencies involved. A VIS program should include information about, and the reasoning behind, land management policy decisions and explanations of timber, wildlife, and watershed management of forest lands.

Public Relations

The orientation of the campsite market area and its size show that news releases with information for campers and potential campers need not be sent beyond an area bounded on the south by a line between Chicago and Cleveland and on the north by the Straits of Mackinac.

The socioeconomic characteristics of these families indicate that they are probably above average in political awareness and activity (Berelson & Steiner, 1964, p. 423). Recent controversies over wildland management policies have shown the political energy of recreationists. The forestry profession has an opportunity to use some of this energy to improve forest resource management.

A FINAL REMARK

At the present time descriptive studies of recreationists are most useful as benchmarks for comparisons over time. Periodic studies will be needed to detect possible changes in the kinds of people who participate and how they participate in forest recreation. These will provide necessary information to understand relationships between user characteristics and user behavior. As more knowledge is gained about these relationships, the general usefulness of descriptive studies will increase.

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ESTIMATING CROWN FUEL WEIGHTS OF RED PINE AND JACK PINE

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CONTENTS

Page

INTRODUCTION 1

STUDY PROCEDURES AND MEASUREMENTS TAKEN 1

PREDICTION OF CROWN MATERIAL 2

The Variables Studied and Equations Developed 2

Live Crown Weight Per Tree 2

Total Crown Weight Per Tree 5

Crown Weight Per Cord 5

Needle Quantities 5

FUEL QUANTITY APPLICATION 9

Slash Accumulations 9

Fire Spread and Intensity 9

SUMMARY AND CONCLUSIONS 11

LITERATURE CITED 12

Estimating Crown Fuel Weights of Red Pine and Jack Pine

by James K. Brown

INTRODUCTION

Fuel weight is a major factor influencing the intensity of forest fires. Moisture content, fineness, compactness, and continuity of fuel, as well as prevailing weather conditions, also influence fire intensity since they affect both the amount of fuel available for combustion and the rate of burning. Behavior of fires results from the complex interaction of these factors. Fuel weight, however, is one of the most important considerations in describing fuel hazard since it determines potential fuel energy release and remains reasonably constant over time. Weight of tree crowns, the subject of this paper, is a particularly important component of forest fuels during crown fires or slash fires.

Previous studies have shown that crown weight of many conifer species can be predicted from bole diameter and crown length of individual trees (Kittredge 1944; Storey et al. 1955; Fahnestock 1960; Wendel 1960; and Brown 1963). The trend of increasing crown weight with increasing bole diameter is similar for some species but varies considerably among others because of physical differences in foliage and habit of branching. Very little previous research adequately identifies the variation in crown weight due to site quality and stand density.

This paper describes for red pine (*Pinus resinosa* Ait.) and jack pine (*Pinus banksiana* Lamb.) the relationship between weight of individual crowns and different conditions of site quality and stand density. It also presents a simple method for estimating the crown weights of these species. This method is applicable for estimating both overstory fuel in uncut stands and the amount of slash created by thinning or harvest cutting.

STUDY PROCEDURES AND MEASUREMENTS TAKEN

The data were collected in 1962 and 1963 on the Huron-Manistee National Forests in Lower Michigan. Dominant and codominant trees were randomly selected from 1-inch d.b.h. classes over a range of 2 to 9 inches from stands on good and poor sites at high and low densities. Extremely lopsided crowns, such as occur on trees at the border of plantations, were not accepted.

Site index was determined from the 5-year internode length above breast height for red pine (Day et al. 1960) and from tree height at age 50 for jack pine. The site index of sampled red pine stands averaged 72 on good sites and 49 on poor sites; for jack pine it averaged 62 on what was termed good sites and 43 on poor sites.

Stand density was measured (1) for each red pine by tallying all trees within a 1/40-acre plot, including the sample tree located at the plot center, and (2) for each jack pine by computing the average spacing between the sample tree and all surrounding competing trees. For good and poor sites combined, the sampled stands had the following number of trees per acre for high-density and low-density conditions:

NOTE: The author is Associate Fire Control Specialist at the Lake States Forest Experiment Station, which is maintained at St. Paul, Minn., by the Forest Service, U.S. Department of Agriculture, in cooperation with the University of Minnesota.

	Diameter class (inches)		
	2-4	5 and 6	7-9
High-density stands			
Red pine	1,190	980	690
Jack pine	2,340	1,090	810
Low-density stands			
Red pine	550	400	440
Jack pine	490	360	300

Altogether, 103 red pines were selected from 13 plantations between 11 and 45 years old, and 95 jack pines from 9 plantations and natural stands between 15 and 47 years old. Stand age was based on age of trees beginning with 3-year-old seedlings.

Trees were severed at ground level and all branches lopped flush with the bole. Tops of trees were cut off at a diameter of 1.5 inches and, together with the branch material, were weighed by means of a dynamometer suspended from an A-frame.

Live crown length, tree height, d.b.h., age, crown competition, and site index were recorded for each sample tree.

Estimates of needle weight for individual red pines were obtained by stripping foliage from 1 branch per whorl from 24 trees of different diameters and stand conditions. These needle samples were weighed, then expanded to a per-tree basis according to the number of branches in each whorl. Moisture samples of branchwood and needles showed that moisture content averaged 110 percent of dry weight. By means of this figure, green weights of all red pine crown material were reduced to dry weights.

Needle weight for individual jack pines was also estimated from 24 trees of different diameters and stand conditions. For this species, however, the branches from the upper two-thirds of the tree were kept separate from those of the lower one-third; the latter was expected to have, and actually did have, a lower proportion of needle weight to branchwood. For each of these two parts of the crown, sample branches were chosen and stripped of needles. Branches and foliage were then weighed. The green needle weight was next calculated as a percentage of the total. This percentage, applied to the total weight of all branches and foliage in that portion of the tree, gave the total green needle weight. Dry weights were obtained on an individual tree basis, using moisture content percentages obtained from foliage and branchwood for the adjustment.

Estimates of needle weight for both species are representative of foliage conditions from the time of needle fall in the autumn to about July, when new summer growth becomes appreciable. They do not include new foliage developed during the summer.

PREDICTION OF CROWN MATERIAL

The Variables Studied and Equations Developed

The data for each tree species were subjected to linear regression analyses (table 1). In most cases logarithmic transformation of dependent variables improved estimates.

The best equations for estimating crown weight per tree and per cord with the smallest standard error are shown in table 2. Although only trees with dominant and codominant crowns were sampled, the findings of this study probably apply to intermediate and suppressed trees as well; the relationship between foliage or crown weight and dimensions of the stem has been shown to be similar for all crown classes (Kittredge 1944; Storey et al. 1955). Normally dominant trees have large crowns and large diameters, while suppressed trees have small crowns and small diameters.

Live Crown Weight Per Tree

Of all the independent variables tested, d.b.h. and crown length x d.b.h. resulted in the most precise relationships with crown weight per tree. D.b.h. was the best single predictor of crown weight per tree for both red and jack pines. This proves helpful in actually predicting crown fuel weights because d.b.h. is easily measured.

TABLE 1. — *Crown fuel variables and tree characteristics examined for red pine and jack pine stands growing on good and poor sites at high and low densities; X means the variable was investigated*

Item	Jack pine	Red pine
INDEPENDENT VARIABLES		
D.b.h.	X	X
Tree height	X	X
Crown length	X	X
Bole length	X	
D.b.h. x crown length	X	X
D.b.h. x tree height	X	X
D.b.h. x bole length	X	
Age	X	X
Site index	X	X
Basal area/acre	X	X
Number of trees/acre	X	X
DEPENDENT VARIABLES		
Dead branch weight/tree	X	
Live crown weight/tree	X	X
Total crown weight/tree (dead branches plus live crown)	X	
Live crown weight/cord		X
Total crown weight/cord	X	

TABLE 2. — *Equations for predicting the crown weight (lbs. oven-dry basis) per tree and per cord from d.b.h., number of trees per acre, site index, and age of stand for red and jack pines*

Species	Equation[1]	R^2 *	Standard error of estimate
Red pine	Log (live crown weight/tree) = .9990 + .0946 (d.b.h.) + .003614 (SI) — .0002722 (trees/ac.)	.86	.0961
Red pine[2]	Log (live crown weight/cord) = 5.2947 — .0318 (stand age) — .000162 (trees/ac.) — .0160 (SI)	.78	.1119
Jack pine	Log (total crown weight/tree) = .8234 + .133 (d.b.h.) + .003393 (SI) — .0001127 (trees/ac.)	.90	.1234
Jack pine	Log (live crown weight/tree = .9733 + .1148 (d.b.h.) — .0001556 (trees/ac.)	.82	.1605
Jack pine	Log (dead branch weight/tree) = .2087 (d.b.h.) — .0978	.78	.2491
Jack pine[2]	Log (total crown weight/cord) = 5.1125 — .0269 (stand age) — .000166 (trees/ac.) — .0135 (SI)	.78	.1260

[1] *SI = site index.*

[2] *In addition to sampling error, an unknown amount of error exists in this equation because crown weight per cord was calculated from volume table values, not measured for each tree.*

* R^2 *measures the proportion of the variation about the mean accounted for by the independent variables.*

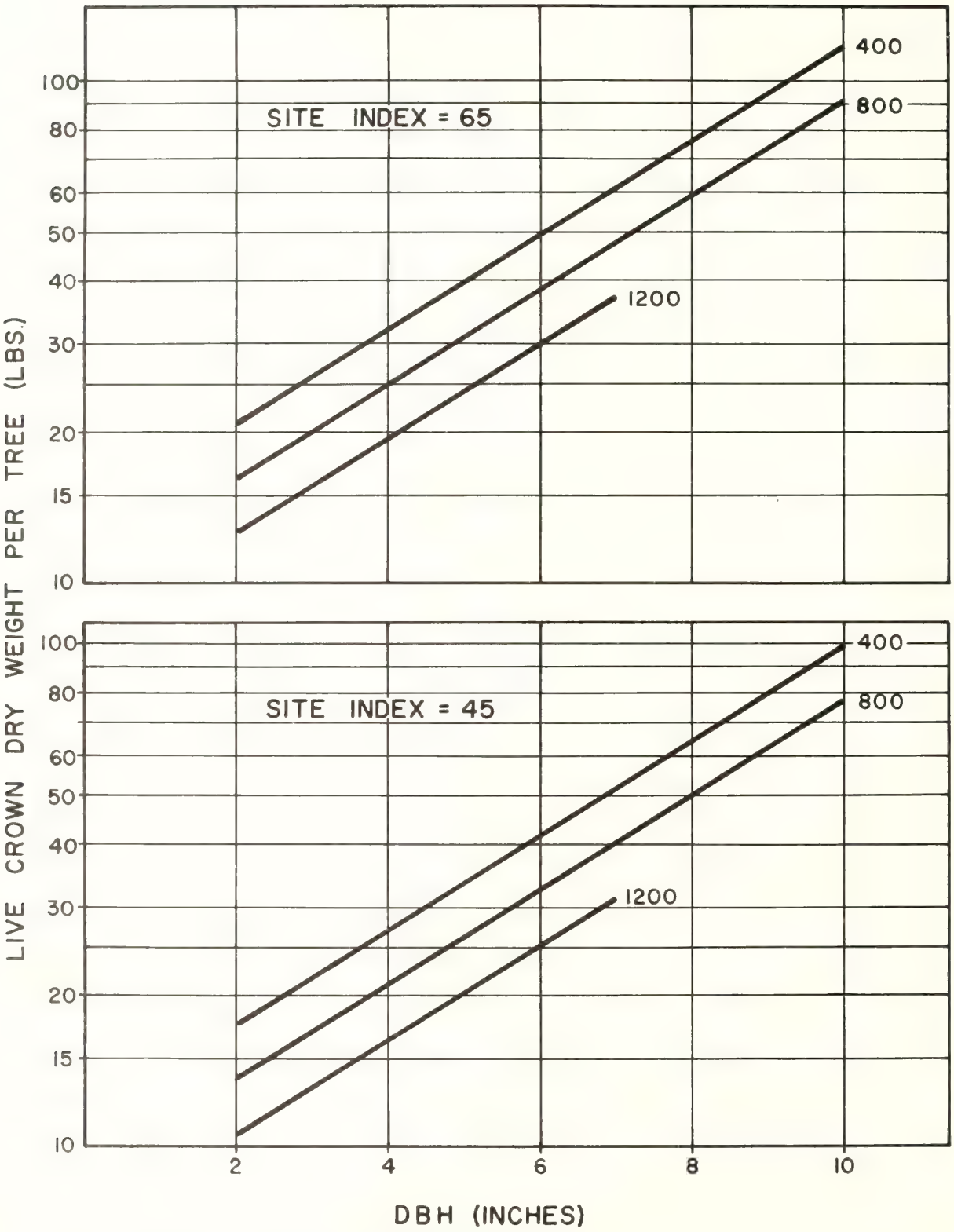

FIGURE 1. — Live crown weight of red pine trees for different diameters, numbers of trees per acre, and two site indexes. Equations for these curves are shown in table 2.

Neither number of trees nor basal area per acre merited use as single predictors of fuel weights. For use in multiple regression equations, number of trees per acre, however, was a considerably better measure of stand density than was basal area per acre.

Figure 1 shows the relationship between live crown weights of red pine and d.b.h. for two site indexes and three stand densities. Comparing trees of the same d.b.h., individual crowns on good sites weigh more than crowns on poor sites, and crowns from low-density stands weigh more than crowns from high-density stands. This is also true for live crown weights of jack pine.

Total Crown Weight Per Tree

Dead branches on jack pines were weighed and added to live crown material, yielding values of total crown weight per tree. The relationship between total crown weights of jack pine and d.b.h. for two site indexes and four stand densities is shown in figure 2. As with live crowns for trees of the same d.b.h., individual total crowns on good sites weigh more than those on poor sites, and total crowns from low-density stands weigh more than those from high-density stands.

The weight of dead branches on individual trees related closely to d.b.h. Site and stand density did not significantly improve prediction of dead branchwood per tree over the prediction based on d.b.h. alone.

An investigation by LaMois (1958) provides estimates of the weight of dead branches on red pine (see section on Fuel Quantity Application).

Crown Weight Per Cord

In an attempt to find an easy way of estimating the amount of slash generated from logging operations, crown weight per cord was computed and held as a dependent variable in regression with age and d.b.h. Age of stand correlated highest with crown weight per cord, and since age is often known or easily determined by forest managers, it makes a convenient predictor.

Crown weight per cord was obtained by first determining the cordwood volume in each sample tree, then calculating the number of trees per cord (1.0 divided by cordwood volume per sample tree), and finally multiplying this volume by crown weight per tree. Volume for each sample tree was arrived at from a cordwood volume table based on a 3-inch merchantable top (Gevorkiantz and Olsen 1955).

At any given age, over the range dealt with here, the amount of crown weight per cord of red or jack pine was greater on poor sites than on good sites (figs. 3 and 4). Trees on poor sites with small diameters contained considerably less merchantable cordwood volume than the larger trees on good sites; hence crown weight per cord was greater on poor sites. Similarly, crown weight per cord in high-density stands is less than in low-density stands because tree competition in dense stands retards branch growth on individual trees.

Needle Quantities

The percent needle weight in live crowns averaged 43 percent for red pine and 21 percent for jack pine, a marked difference between the species. Neither site quality nor stand density greatly influenced the proportion of needle weight to live crown weight, particularly with jack pine (fig. 5). Small but reliable differences in percent needle weight due to growing conditions were observed for red pine.

Crowns from good sites held more foliage per unit weight of branchwood than those from poor sites. Similarly, crowns from high-density conditions contained more foliage per unit weight of branchwood than those from low-density conditions. Even though the ratio of needles to branchwood was higher in high-density stands, trees grown in these stands yielded a smaller total quantity of needles than trees grown under light competition.

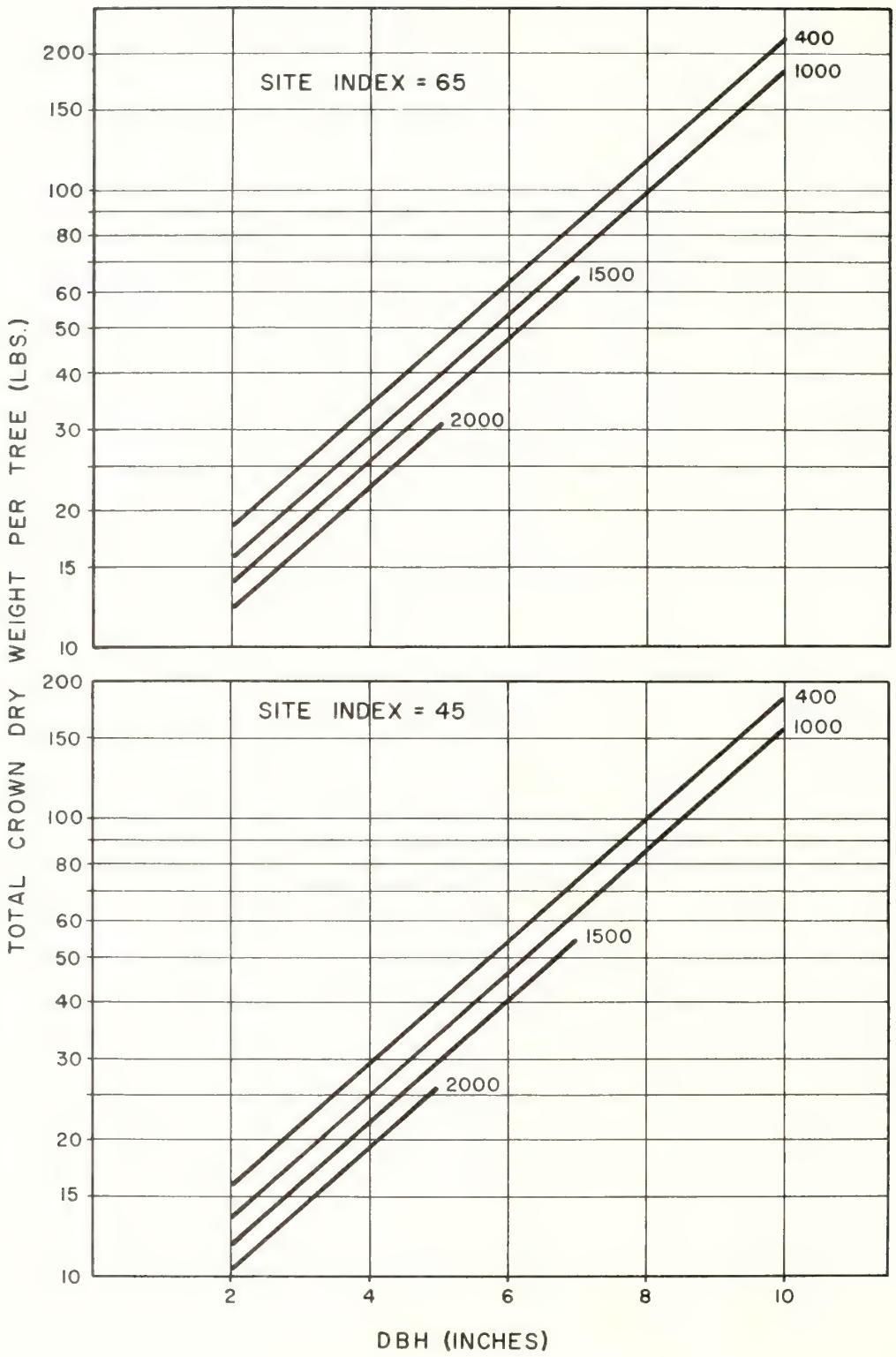

FIGURE 2. — Total crown weight (dead and live branches) of jack pine trees for different diameters, numbers of trees per acre, and two site indexes. Equations for these curves are shown in table 2.

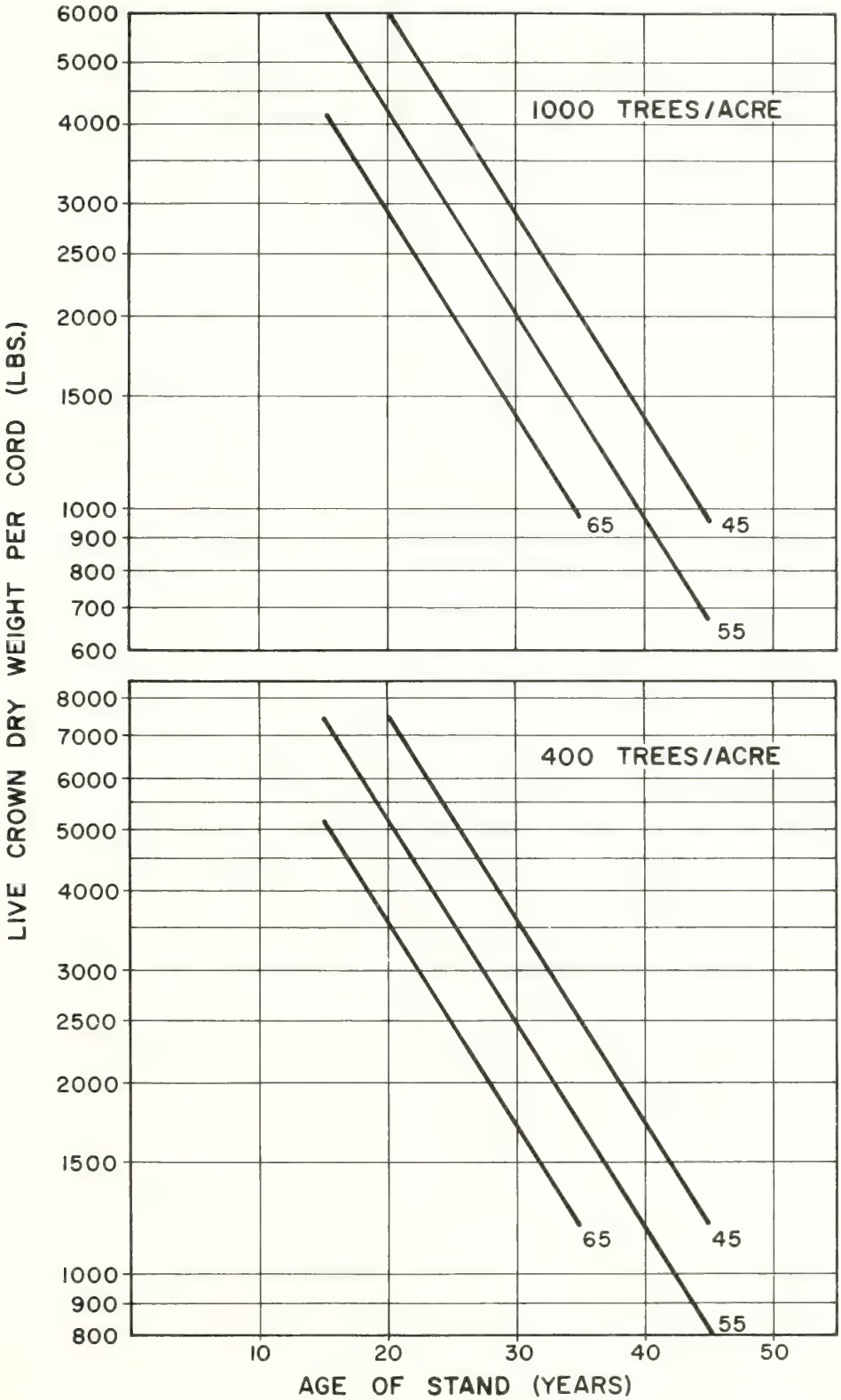

FIGURE 3. — Red pine live crown weight per cord according to age of stand, site index, and two stand densities. Equations for these curves are shown in table 2.

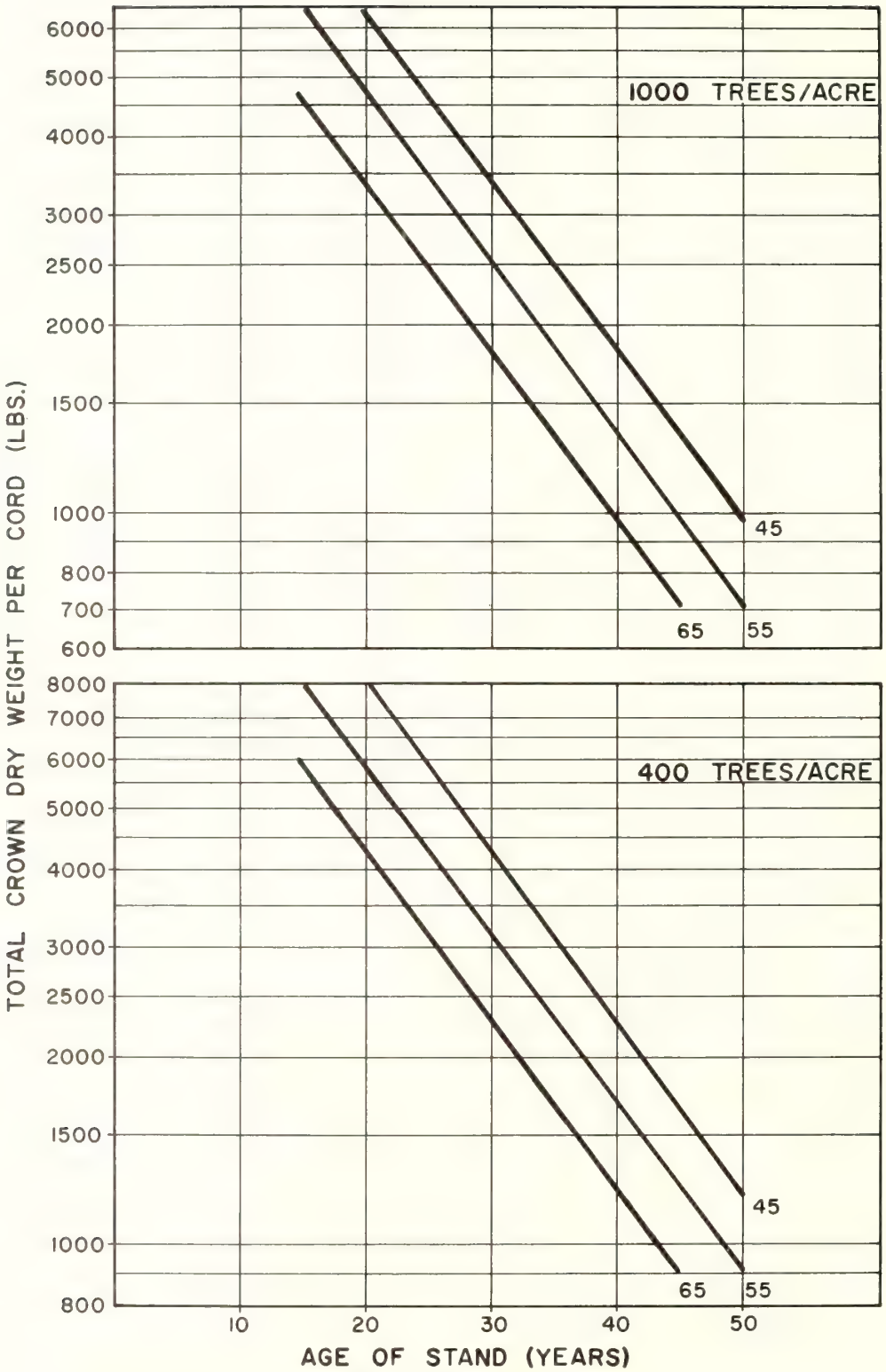

FIGURE 4. — Jack pine total crown weight (live and dead branches) per cord according to age of stand, site index, and two stand densities. Equations for these curves are shown in table 2.

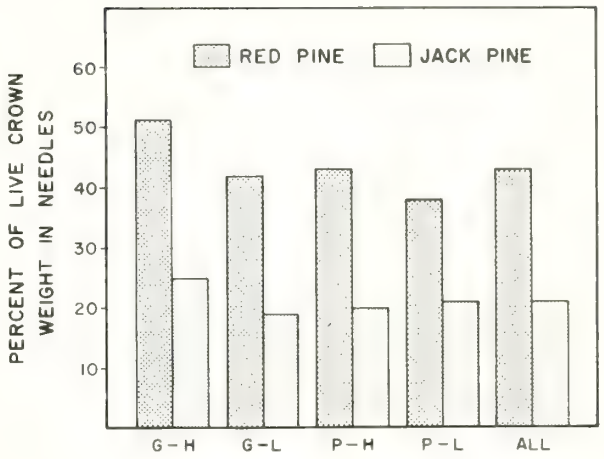

FIGURE 5. — Percent live crown weight in needles for red pine and jack pine on good (G) and poor (P) sites at high (H) and low (L) densities. Actual values for site index and stand density are averages of field conditions sampled and are not exactly the same for both species. Percent needle weight is based on 6 observations in each stand condition, or 24 observations overall with a standard error of the mean of 1.5 percent.

FUEL QUANTITY APPLICATIONS

Slash Accumulations

The quantity of slash resulting from a cutting operation can be estimated by (1) determining the site and density of the stand, (2) multiplying the number of trees harvested in each diameter class by the proper crown weight per tree, which is obtained from figures 1 or 2 or the appropriate equations, and (3) totaling these results through all diameter classes. If site index or stand density falls between standards used in this study, interpolation of crown weight will improve the outcome.

To include dead branches on red pine in estimating accumulation of slash per acre, results of LaMois' (1958) study can be applied. For red pine 4 inches in d.b.h. and larger, 5,000 pounds (dry weight) of dead branchwood per acre may be found on good sites and 2,500 pounds on poor sites. Red pine stands older than 30 years probably support amounts greater than these.

Another way of determining the amount of slash resulting from a cutting operation, knowing age of stand, is to calculate the crown weight per cord, using figure 4 or 5 or the appropriate equation. Again, interpolation of crown weight between site and density standards presented in the charts will improve results. Number of cords harvested multiplied by the crown weight per cord equals the quantity of slash created. Several examples of predicted crown fuels encountered in red and jack pine stands are described in table 3 and figures 6 and 7.

Fire Spread and Intensity

Quantity of fuel substantially affects rate of spread and fire intensity. Several findings from a study by Fahnestock (1960) should be generally applicable to red and jack pine crown fuels. He reported that, as a rule-of-thumb, rate of spread in slash over a wide range of relative humidities but at low wind velocities increases 6 percent for each ton of fuel added to an acre. This holds about equally true for fresh and 5-year-old slash (Fahnestock and Dieterich 1962). Fuel quantity of Rocky Mountain species had a stronger effect on fire intensity than on rate of spread. Fire intensity was three times higher in test plots of 32.5 tons per acre than in plots of 20 tons per acre (Fahnestock 1960).

TABLE 3. — *Dry weight per acre of live and dead crown material (excluding bolewood over 1.5 inches in diameter) estimated for three stand conditions typical of pine plantations in Lower Michigan*

Species	Silvicultural condition	Age	Site index	Trees per acre	Needle weight	Total crown weight
		Years		*Number*	*Tons*	*Tons*
Jack pine	Slash from clear-cut operation	50-60	45	500	6½	30
Red pine	Uncut	25	70	1,000	9	20
Red pine	Slash after thinning from 150 sq. ft. to 100 sq. ft. of basal area	25	70	1,000	3½	8
Red pine	Uncut	15	70	1,200	5	10

F-506849

FIGURE 6. — This 40-year-old jack pine stand on a poor site was severely damaged by the pine tortoise scale (*Toumeyella numismaticum* Pettie and McD.). Salvage logging left 23 tons of slash per acre. Picture taken 3 years after logging.

F-503657

FIGURE 7. — Commercial thinning to 100 square feet of basal area in this 25-year-old red pine plantation containing 1,000 trees per acre on a good site created approximately 8 tons of slash per acre (excluding bolewood over 1.5 inches in diameter).

SUMMARY AND CONCLUSIONS

This paper shows the effect of site and stand density on the crown size of individual red pine and jack pine trees and provides a means of estimating crown fuel weights.

Of all the independent variables examined, d.b.h. related to crown weight per tree with the smallest standard error.

Site and stand density exerted notable influence on crown weight per tree. Similar to normal forest yield-table trends, volume production of crown material for both red pine and jack pine was greater on good sites than on poor sites. It was also greater in low-density stands than in high-density stands. Graphs and equations are presented for predicting crown weight per tree using d.b.h., site index, and stand density as multiple independent variables.

Graphs and equations are also presented for estimating the quantity of crown material per cord of merchantable wood from stand age, stand density, and site index. All three of these factors influence crown weight per cord.

Results of this study show that estimated amounts of foliage and branchwood, on an acre basis, vary according to age and growing conditions of the stand. The expected amount of live crown on an acre composed predominantly of red pine or jack pine of pulpwood size ranges from 7 to 20 tons dry weight.

The proportion of live crown weight composed of needles averaged 43 percent for red pine and 21 percent for jack pine. Site and stand density exerted a slight influence over this proportion.

Research on the physical characteristics of fuels is directed toward understanding fire behavior in such a way that diverse levels of fire hazard can be recognized, particularly circumstances encouraging to high-intensity

and conflagration-type fires. With increasing knowledge, a national system of rating fire ignition, intensity, and blowup potential may eventually be possible, but as yet the intricacy of fire and fuel relationships requires further exploration. A system of classifying the vertical and horizontal distribution of forest fuels according to their particle size and surface area would aid considerably in solving problems of predicting fire behavior.

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BALSAM FIR DIMENSION LUMBER IN SELECTED MINNESOTA MARKETS

by

E.M. CARPENTER
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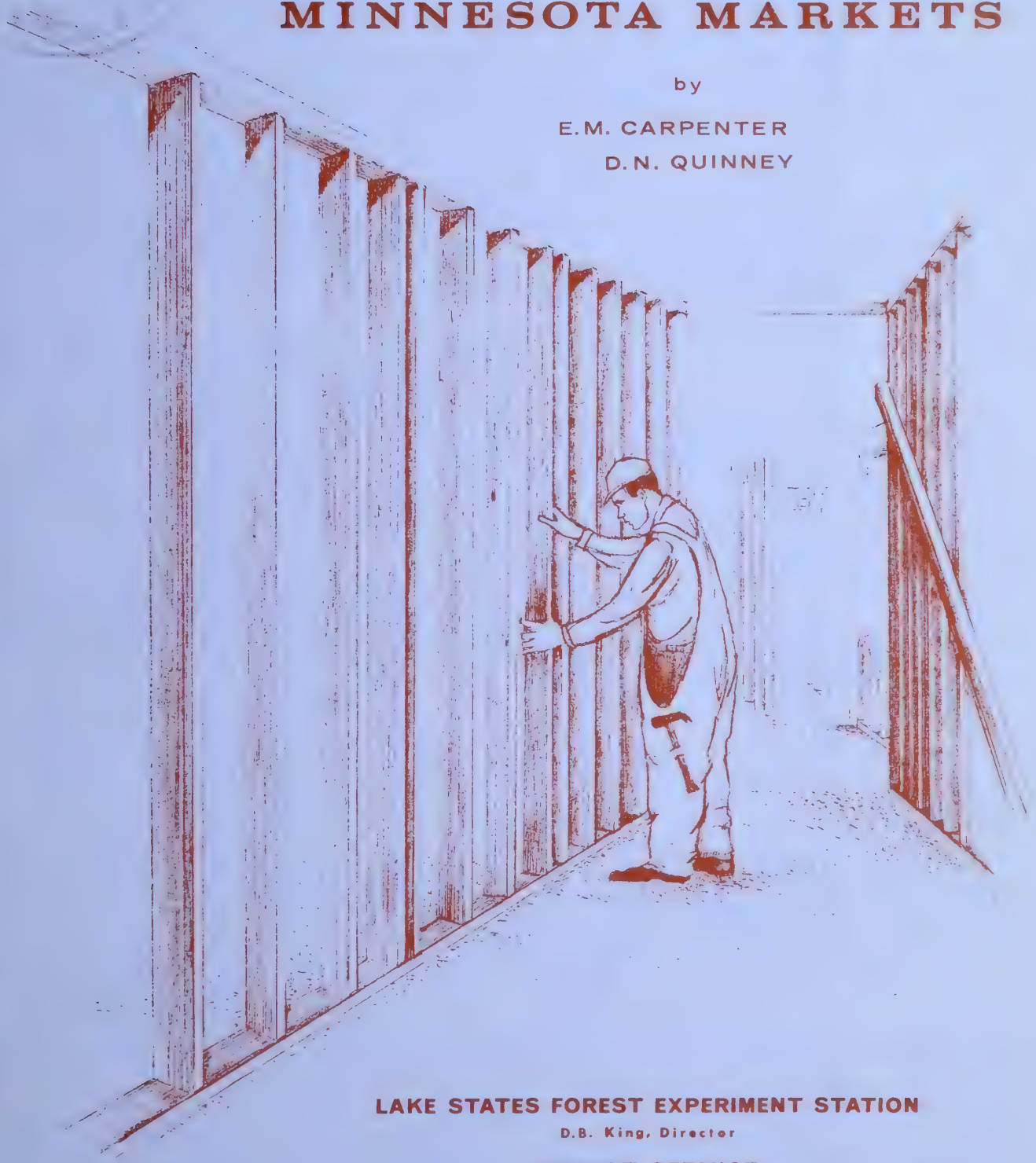

LAKE STATES FOREST EXPERIMENT STATION
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CONTENTS

Page

INTRODUCTION 1

BALSAM FIR — SUPPLY, DEMAND, PROPERTIES 1

THE STUDY 4

USE AND KNOWLEDGE OF BALSAM FIR 5

- Present Use as Dimension Lumber 5
- Type and Volume of Material Used 5
- Source of Material 5
- Buyers' Uses and Satisfaction 5
- Marketing Problems 6

POTENTIAL MARKET FOR BALSAM FIR 7

- Volume of Other Species Sold 7
- Grade and Price of Balsam Fir 8
- Ways to Increase Use of Balsam Fir 9
- Competitive Production Methods 11

SUMMARY AND CONCLUSIONS 12

Balsam Fir Dimension Lumber In Selected Minnesota Markets

by

E. M. Carpenter and D. N. Quinney

INTRODUCTION

In 1964 the Lake States Forest Experiment Station explored the use and acceptance of balsam fir dimension lumber in two Minnesota market areas. The reasons for making the study were several: Although large supplies of balsam fir are available in the Lake States, it is a much under-used species. Furthermore, its greatest use has been as pulpwood, but its share in the pulpwood harvest has been declining. Obviously, other markets are needed for balsam fir. That forest and mill owners are aware of this is indicated by several inquiries directed to the Station on market possibilities.

This report presents the results of the study and suggests that there may be opportunities for increased marketing of balsam fir as 2x4 dimension lumber.

BALSAM FIR — SUPPLY, DEMAND, PROPERTIES

The spruce-balsam fir type covers slightly more than 4 million acres in the Lake States. This represents a little less than 8 percent of the commercial forest area. In terms of volume, balsam fir totals almost 12 million cords — about 14 percent of the softwood and 3.5 percent of the total timber volume (fig. 1). Balsam fir, however, is a problem species with respect to utilization and marketing.

An estimated 95 percent of the balsam fir harvested is cut for pulpwood. Over the last 15 years this cut has fluctuated considerably, but over time it has shown a slight decreasing trend (table 1).

During this time the total Lake States production of pulpwood jumped from 693,000 cords in 1946 to 3,628,000 cords in 1964 — an increase of nearly 525 percent. The failure of the balsam fir pulpwood harvest to show increases was not due to a declining resource; on the contrary, inventory data show that the volume of merchantable-size balsam fir has increased considerably over the last several decades. The primary cause probably is changes in technology, which have permitted a greater use of aspen and other hardwoods in various pulping processes. Supplies of

TABLE 1. — *Production of balsam fir for pulpwood in the Lake States, 1946-1964*
(*In thousands of cords*)

Year	Total production	Year	Total production
1946	257.6	1956	304.1
1947	311.6	1957	379.9
1948	400.8	1958	293.6
1949	319.4	1959	291.6
1950	318.0	1960	330.6
1951	347.9	1961	285.9
1952	391.5	1962	260.0
1953	248.3	1963	283.6
1954	311.4	1964	232.4
1955	289.4		

Source: The annual reports on pulpwood production in the Lake States published by the Lake States Forest Experiment Station, St. Paul, Minn.

Note: The authors, E. M. Carpenter, Associate Market Analyst, and D. N. Quinney, Principal Economist, are headquartered at the Station's field office in Duluth, which is maintained in cooperation with the University of Minnesota Duluth.

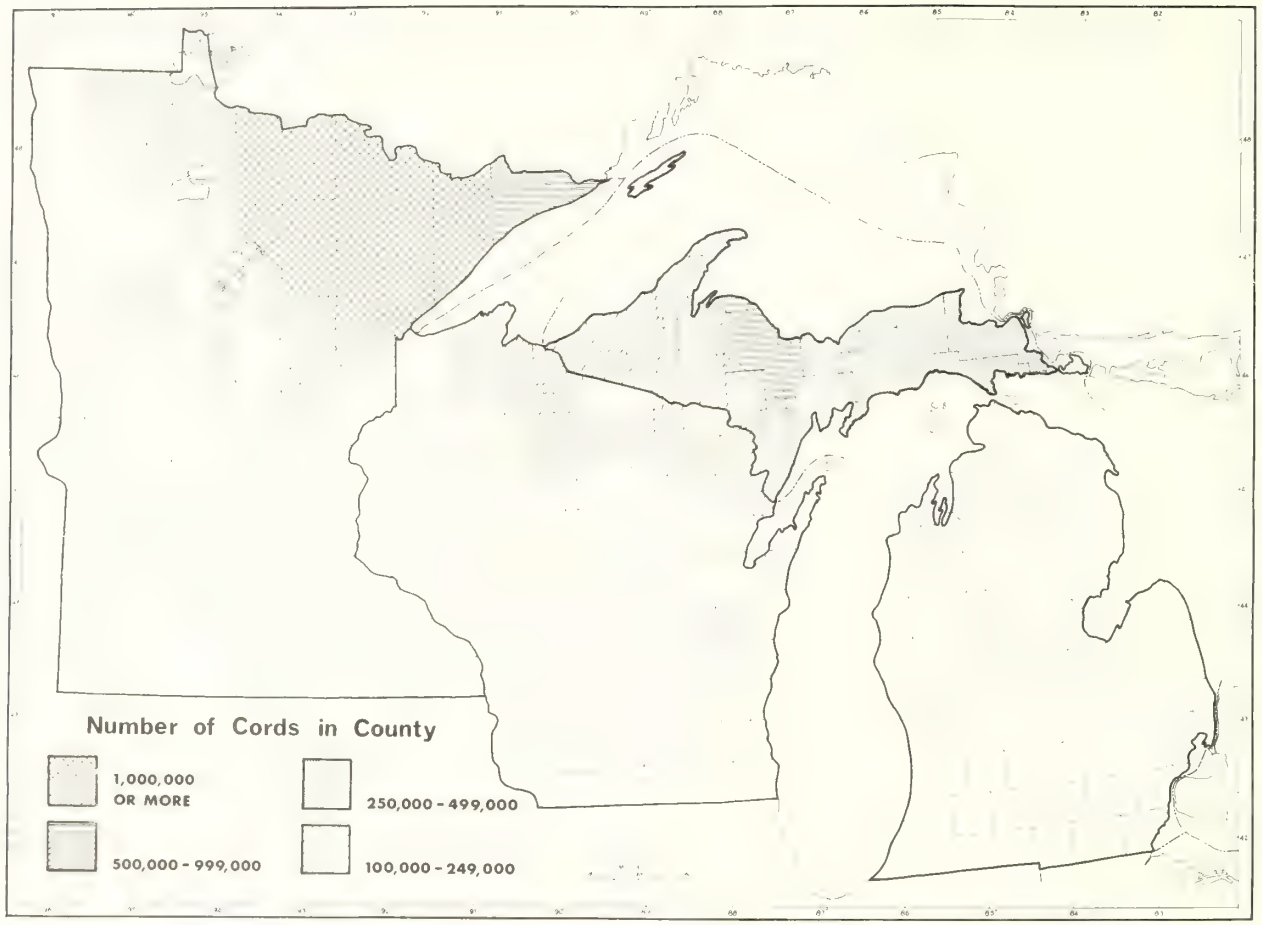

FIGURE 1. — Cordwood volume of balsam fir growing stock in the Lake States. Northeastern Minnesota and Michigan's Upper Peninsula have heavy concentrations of balsam fir timber. Data were obtained from county forest resource reports published for Wisconsin between 1955 and 1958 by the Wisconsin Conservation Department, for Michigan between 1948 and 1957 by the Michigan Department of Conservation, and for Minnesota between 1960 and 1962 by the Office of Iron Range Resources and Rehabilitation. Data were collected and reports published in cooperation with the Lake States Forest Experiment Station.

these species are nearer many of the pulpmills than are balsam fir supplies. Also working against an increased use of balsam fir in the Lake States pulp and paper industry is its low density in relation to unit volume. Balsam fir pulpwood yields less cellulose per unit volume and, under present cost conditions, per unit value than do the spruces or jack pine.[1]

In northern Minnesota especially, balsam fir is an under-used species. Comparisons of timber cut figures for 1953 and 1960 show that the cut of balsam fir growing stock declined by almost 20 percent, in spite of increasing volumes of available fir timber. For this northern area the latest Minnesota Forest Survey figures show that balsam fir timber volume jumped from 5,510,000 cords in 1953 to 8,917,000 cords in 1962, a 62-percent increase. The survey also revealed that in northeastern Minnesota the number of 2- and 4-inch fir trees exceed the number of aspen trees in the same size classes. In the aspen forest type, which covers 1,950,400 acres, balsam fir ranks third in volume (932,000

[1] *U.S. Forest Service. Feasibility of using Lake States hardwoods for newsprint and other pulp and paper products. 84 pages, illus., 1959.*

cords) behind aspen (11,974,000 cords) and paper birch (1,051,000 cords). All other species are far below these figures in this type. Increased markets would give loggers a chance to profitably remove this material from these mixed stands.

Aggravating this problem of under-use are the volumes of balsam fir which might be salvaged from decadent overmature stands. Being a relatively short-lived tree, balsam fir does not "store on the stump." By the time a log-size of 10 inches is attained, many fir stands are showing signs of deterioration, with rot and ring shake taking a heavy toll in the saw log size trees.[2] The salvage of this material would not only help prevent a waste but also provide the management measures necessary to guard against further insect infestation by offering an opportunity for orderly harvest of these stands.

In addition to its use for pulpwood, some balsam fir is manufactured into lumber and dimension stock. In 1961 northern Minnesota sawmills sawed a little more than 4 million board feet of balsam fir.This material is produced in relatively small amounts by many small and medium-size mills. Seldom do the larger mills saw any significant amount on their headrigs; they may purchase a smaller mill's output, rough green or rough dry, for further finishing and marketing by their own organization.

Balsam fir, even when mature, is a small- to medium-size tree, averaging 40 to 60 feet tall and 12 to 18 inches d.b.h.[3] Further aggravating this size problem is the fact that, in the Lake States, average stands are much smaller than this; more usual are trees of 8 to 10 inches d.b.h. and 45 to 55 feet tall (fig. 2).[4] Thus the sizes of material that could be manufactured are limited. In the Lake States,

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FIGURE 2. — Much of the balsam fir suitable for studs would come from poletimber stands. The logs being loaded here have a minimum 5-inch top, and run heavily to 6- and 8-inch sizes.

most of the second-growth balsam fir stands in 1953 were in poletimber or small-sawtimber tree sizes as shown below.

D.b.h. class (inches)	*Million cords*	*Percent of total*
5.0 — 6.9	4.7	40
7.0 — 8.9	3.8	32
9.0 — 10.9	2.1	18
11.0 — and larger	1.2	10
All size classes	11.8	100

Source: Cunningham, R. N., and Survey Staff. Lake States timber resources. U.S. Forest Serv. Lake States Forest Expt. Sta., Sta. Paper 37, 31 pp. 1956.

In terms of physical characteristics, balsam fir wood is rated as light in weight, low in bending and compression strength, moderately limber, soft, and low in ability to resist shock. It shrinks only moderately in drying, is not difficult to season, and is not likely to split in the nailing process, but is said to be

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[2] *Kaufert, Frank H. Heart rot of balsam fir in the Lake States, with special reference to forest management. Univ. Minn. Agr. Expt. Sta. Tech. Bul. 110, 27 pp. 1935.*

[3] *Harlow, W. M., and Harrar, E. S. Textbook of dendrology. 4th ed., 561 pp. New York: McGraw-Hill Book Co. 1958.*

[4] *Roe, Eugene I. Balsam fir in Minnesota — a summary of present knowledge. U.S. Forest Serv., Lake States Forest Expt. Sta. Misc. Rpt. 13, 25 pp. 1950. St. Paul, Minn.*

low in nail-holding ability.[5] [6] In the last respect, it is rated the same as western white fir, spruce, lodgepole pine, and eastern hemlock. Balsam fir lumber of suitable grade is usable in house construction, and standards for such use are provided in the Property Standards of the Federal Housing Administration.

THE STUDY

Because both the wholesale and retail seller of lumber are major determinants in the choice of wood species, the study was aimed at these market functionaries. It included canvassing retail and wholesale merchants, both in the 16-county area commonly referred to as the northern forested region of Minnesota and in the Minneapolis-St. Paul metropolitan area (fig. 3). The two areas were chosen because of the possibility of revealing contrasts in the use of balsam fir between the northern areas, where direct mill-to-yard marketing relationships are common, and the more complex supply channels of the metropolitan market.

A list was assembled comprising 102 retail and 20 wholesale firms in the northern area, and 98 and 66 firms, respectively, in the Twin Cities area. A 25-percent sampling of firms was made in each category in each area. An interview schedule was prepared, and the owner, manager, or other responsible official for each firm in the sample, was personally interviewed in the fall of 1964.

The objectives of the study were to determine:

1. The volumes of balsam fir dimension stock handled by wholesale and retail sellers in northern Minnesota and the Twin Cities in 1963.

2. The sources and prices of this material, the purposes for which it was sold, and apparent buyer satisfaction with the product.

3. The degree of sellers' familiarity with the physical properties of balsam fir; their opinions as to its suitability as dimension lumber; and whether poor or insufficient information on the species' physical properties and performance is hindering its use.

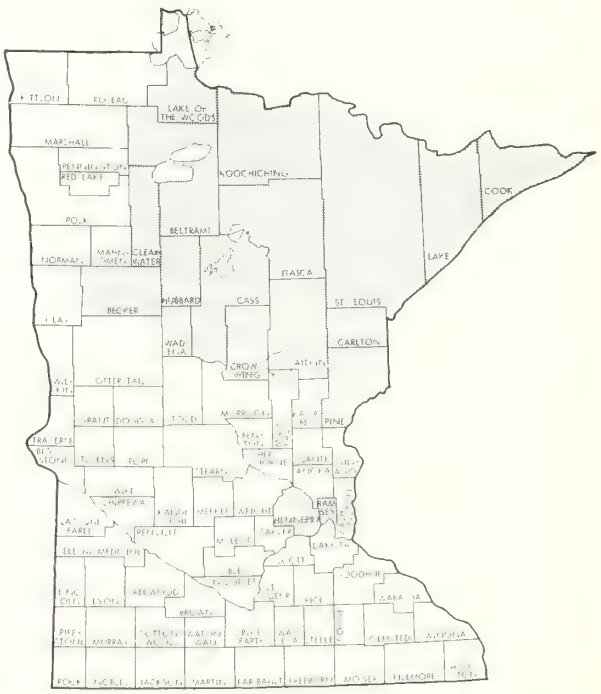

FIGURE 3. — Wholesale and retail lumber yards were sampled in the Twin Cities area and in 16 northern Minnesota counties.

[5] *U.S. Forest Service. Wood handbook. U.S. Dept. Agr. Handbook 72. 528 pp. 1955.*

[6] *Betts, H. S., et al. Balsam fir. American Wood Series, U.S. Forest Serv. 8 pp. 1945.*

USE AND KNOWLEDGE OF BALSAM FIR

Present Use as Dimension Lumber

A substantial difference exists between Minneapolis-St. Paul and northern Minnesota retail lumber yards in the sale of balsam fir as construction dimension lumber. In the northern area, where most yards obtain at least a portion of their lumber from nearby sawmills or directly from their own mills, survey sample figures show that over 75 percent handle balsam fir (19 out of 25 yards sampled), while in the Twin Cities area the proportion is only 8 percent (2 out of 25 yards).

None of the sampled Twin Cities lumber wholesalers handled balsam fir. Of course, none of these dealers were connected with Lake States sawmills, their primary function being that of a wholesale yard or broker. A few were direct sales outlets for western sawmills.

In northern Minnesota, of five wholesalers interviewed who handle dimension lumber, two carry balsam fir. Both of these operate their own sawmills. Two of the three who did not handle balsam fir were brokers who catered principally to industrial accounts and had no market for this type of material. One, a sawmill, is primarily a northern hardwood producer.

Type and Volume of Material Used

The two metropolitan retail yards in the sample using balsam fir in 1963 reported that their 108,000 board feet were purchased air-dried planed, about half in 2x4's and half in 2x6's. In the northern area, of a total 590,000 board feet retailed in 1963, 445,000 feet were purchased air-dried planed, 30,000 feet kiln-dried planed, and approximately 100,000 feet air-dried rough, with planing done by the retail yard. Of the 590,000 feet, 530,000 were accounted for by studs, 45,000 by other 2x4's, and 15,000 by 2x6's.

Source of Material

In the Twin Cities area, of the two retail lumber dealers sampled who used balsam fir in 1963, one obtained his supply from another yard in a special sale, and the other got his through a lumber broker.

Of the 19 retail yards sampled in the northern area that handle balsam fir, 14 dealt directly with independent sawmills, 3 used their own sawmill production, 1 bought from a contract sawmill, and 1 from a broker. The marketing channel most commonly used in northern Minnesota — direct sawmill purchase — undoubtedly developed because of the nearness of yards to mills.

Buyers' Uses and Satisfaction

Because of the small amount of balsam fir marketed in the Twin Cities area, it was impossible to determine a predominant end use, although it was surprising to find a fair portion of the volume marketed as 2x6's. Naturally, tree size dictates the maximum size of material that can be sawn, and only a very minor amount is cut wider than 4 inches. From the sales figures related by northern Minnesota respondents the most common use there is as studs in frame buildings, and most of these are used in residential construction (fig. 4).

Satisfaction and acceptance of balsam fir by the northern Minnesota firms surveyed was high, and no particular marketing problems were found. All firms reported that their customers seemed to accept the species well, with satisfaction running from an actual preference for balsam fir to a simple "no complaints" statement. One of the main reasons given for acceptance was that balsam fir stayed straight in use.

Only one northern yard reported it had stopped handling the species, and this only because no competitive supplier was available. One northern wholesaler reported quan-

tity sales to a project builder in the Minneapolis area, who was well satisfied.

In the Twin Cities area, two retail yards currently handle balsam fir and two had handled it in the past. Three of the four reported good customer satisfaction. One ceased carrying it because he could not find a reliable supplier at a competitive price. The fourth stopped using balsam fir because he felt that its nail-holding ability was insufficient for scaffolding construction where nails may not be driven flush, and also that heavy garage doors could not be nailed directly to the studs.

The first two data columns in the tabulation below show the number of yards reporting various uses of balsam fir in 1963. The third column shows the number of yards not now handling balsam fir but who think it may have potential uses for their customers.

	Present		*Potential*
Use	*Northern Minnesota*	*Twin Cities*	*Twin Cities*
Residential construction	18	—	12
Commercial construction	2	—	—
Cabins	2	—	—
Garages	2	2	4
Basement rooms	—	2	3
Do-it-yourself projects	8	2	4
Project builders	—	—	1

Obviously there is some overlapping of categories. "Do-it-yourself" probably would often include basement rooms and garages. Also, yards that sold balsam fir dimension stock for residential construction probably sold some for other uses.

The number of yards that sell or expect to sell balsam fir to various types of customers is shown below:

	Yards selling to—		
	Contractors	*Do-it-yourself*	*Project builders*
At present:			
Northern area	19	8	—
Twin Cities	—	2	—
Potential:			
Northern area	3	4	—
Twin Cities	12	8	1

None of the Twin Cities wholesalers presently handle balsam fir. Of the 10 wholesale firms interviewed who handle construction

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FIGURE 4. — Studs usually account for 15 to 20 percent of the volume of lumber used in house construction.

dimension lumber, 7 said they would be interested in stocking local fir, 1 said he possibly would, and 2 said they would not. One of the firms who expressed negative interest felt that the production of local dimension lumber is too uncertain both from a quantity and quality standpoint. The other "noninterested" firm did not sell studs.

Of the five wholesalers in the survey in northern Minnesota who handled dimension lumber, two carried balsam fir. The other three either did not sell studs, had no customer who used studs, or thought that they could not procure and market it at a competitive price.

Marketing Problems

In both areas, some merchants thought that a wider use might be achieved if producers could supply well-manufactured studs at a more competitive price. Production inefficiency seems reflected in selling prices ranging in the high $80's and low $90's. It is often possible for western woods to compete in this price range in northern Minnesota. Another marketing problem is size of

product; balsam fir is usually sawn into 8-foot, 2x4 studs. Some longer lengths are produced, but very little wider material is sawn. This means a yard must depend on other woods, such as red pine, jack pine, or western species, to provide this wider dimension lumber.

The Twin Cities area may be termed a Douglas-fir market, and some yards handle this species exclusively. Other species found in this market are western white fir,[7] western hemlock, white spruce, larch, lodgepole pine, and cedar. Yards generally carry Douglas-fir in the 2x8 and greater widths and another species, particularly white fir, in the 2x4 and 2x6 widths. Some yards carry Douglas-fir in all widths, with a portion of 2x4 studs supplied by white fir, lodgepole pine, or one of the other species. The latter marketing pattern is a recent trend, coincident with the development of numerous specialized stud mills in the West. Thus it would seem that, although balsam fir could not compete in the 2x6 and larger sizes, opportunities exist for balsam fir in this specialty stud market.

Balsam fir is sometimes sold mixed with other species. The associated spruce tends to twist when not properly dried or stored; because of this, some dealers had formed the belief that fir does the same. Nevertheless, misinformation did not seem to limit the present use of local fir. Small production, lack of reliable suppliers, and high price are probably the primary reasons for low use. The relatively poor quality of manufacture (whether real or imagined) generally associated with local lumber by many metropolitan dealers makes it difficult for the better suppliers to operate in the market. A specialty manufacturer of balsam fir 2x4's would be faced with this problem; and extra promotion plus a consistent supply of well-manufactured material would be necessary to obtain and hold a share of the market.

POTENTIAL MARKET FOR BALSAM FIR

Volume of Other Species Sold

Yards in both northern Minnesota and the Twin Cities generally carry western species — the exception being northern yards that sell only their own mill's output. The metropolitan market, with its high volume requirements, is dependent on western production — local production is not nearly sufficient to satisfy the need. Also, since the bulk of the lumber is sold through large wholesalers, metropolitan marketing channels tend to favor western producers. Price, sustained offerings, reliable grading, and consistent drying and finishing are also important factors in supplying this market. Northern yards also use more western than local lumber, even though the majority handle local species. Size requirements are part of the reason for this, but price and volume are also important.

Since this was an exploratory study, no attempt was made to establish precisely the volumes sold by individual yards. We did try to obtain general volume figures for balsam fir and the several western species in the two market areas. Because some sellers could not estimate volume used by species and width, or even the total volume sold in the study areas, the figures are not complete, but they give a general idea of the relative volumes of various species sold. Both in the Twin Cities and northern Minnesota, western species constituted the great majority of the material handled (table 2).

While large volumes of Douglas-fir were handled by most dealers, the bulk of the comparatively large volumes of white spruce and western hemlock were reported by only a few yards specializing in one of these species. Of the retail yards in the Twin Cities reporting volume used by species, the following tabulation shows the number handling each species:

[7] *Western white fir as used here refers to all of the western true firs collectively, as they are commonly designated by the trade.*

TABLE 2. — *Distribution of species handled by retail yards in the Twin Cities and northern Minnesota, 1963*[1]
(Thousand board feet)

Species	Twin Cities		Northern Minnesota	
	All dimension	2x4	All dimension	2x4
Western:				
Douglas-fir	33,532	8,236	1,506	30
White fir	640	429	1,956	1,232
White spruce	2,550	900	135	34
Hemlock	2,355	225	445	50
Fir and larch	1,050	700	—	—
Cedar	105	80	—	—
Lodgepole pine	1,855	1,785	35	—
Total	42,087	12,355	4,077	1,346
Local:				
Jack pine	—	—	210	110
Red pine	—	—	767	25
Balsam fir	110	60	590	575
Total	110	60	1,567	710
All species	42,197	12,415	5,644	2,056

[1] *Includes only those surveyed firms who could provide data.*

Species	*No of Yards*[1]
Douglas-fir	23
Western white fir	8
Lodgepole pine	6
Western hemlock	5
Western white spruce	3
Balsam fir	2
Western fir and larch	1
Western cedar	1

[1] *This tabulation includes alternates to the 25 yards in the original survey, or a total of 27 yards.*

Nearly all the lodgepole pine was marketed as 2x4's, as was approximately two-thirds of the white fir, fir and larch, and cedar. For Douglas-fir, white spruce, and hemlock, several respondents could only estimate total volume used by species and not by size of material. Thus comparison of the percentage marketed as 2x4's is not possible for these species.

Grade and Price of Balsam Fir

Grade rules are published by several associations (fig. 5). The commonly used dimension lumber grades are Construction, Standard, and Utility for western species; and No. 1, No. 2, and No. 3 for local lumber. Western stocks are often sold in the following combinations: Construction (25% standard), sometimes called Standard and Better; and Construction (25% standard) (10-15% utility), sometimes called Utility and Better. Utility is also sold unmixed. Local dimension is often sold as No. 2 and Better or in some cases, log run or ungraded. As a generalization, the western Construction grade is similar to local Grade No. 1, Standard to No. 2, and Utility to No. 3.

It is difficult to compare prices for western and local grades. Actually average quality for mills using the same rules may differ considerably, particularly in mixed-grade shipments. In addition, some mills supply special grade mixes to certain yards, with the actual mix depending on the price paid.

Table 3 shows price ranges developed during the course of the study. These represent delivered prices to the lumber yards for 2x4's, and hold for both study areas. Prices may tend toward the higher end for western stock in the northern area. Price differences develop because of the wide variety of length

TABLE 3. — *Price ranges paid per thousand board feet for 2x4 dimension lumber by species for firms surveyed in the Twin Cities and northern Minnesota, 1964*
(In dollars)

Species	Grades		
	Utility	Utility and Better	Standard and Better
Douglas-fir	High 60's	Low to mid 80's	High 80's to mid 100's
Fir and larch	Mid to high 60's	Low 80's	High 80's to high 90's
Western hemlock	Mid 60's to low 70's	Low 80's	Mid 80's to low 90's
Western spruce	Low 70's	High 70's to low 80's	Mid 80's
Western white fir	Mid to high 60's	High 70's to mid 80's	Mid 80's to low 90's
Lodgepole pine	Mid 60's	Mid to high 70's	High 70's to low 80's
Balsam fir		No. 3 and better	No. 2 and better
		Mid 60's to mid 70's	Mid 80's to low 90's

combinations in individual shipments, plus other variations such as end waxing, grade marking, and end-branding. Two-by-fours generally bring a lower price per thousand than other widths.

Even though the table indicates comparable price ranges for balsam fir and western white fir, the bulk of the balsam was sold in the low $90's and the western white fir in the mid $80's.

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FIGURE 5. — Grading and grade marking are essential to the successful marketing of construction dimension lumber. FHA regulations require grade marking by agents of an authorized grading association.

Ways to Increase Use of Balsam Fir

Each respondent was asked whether he would be interested in handling balsam fir and how he thought its use might be increased in the dimension lumber market. Many of them expressed an interest provided that certain requirements were met. In general, these requirements were that the product must be kiln-dried, be competitive in price with western species, have a good appearance, and be readily available for repeat orders.

In both market areas, dryness and price were most often mentioned. Significant differences exist between the northern and metropolitan areas as far as dryness is concerned. Northern yards recognized its importance, but several indicated *well*-air-dried material would be satisfactory. In the Twin Cities, most indicated that they would not handle lumber unless it had been kiln-dried. Many of these yards store their stock unprotected in the open or in open-sided sheds, where at least some wetting might occur. Thus, some firms apparently place great emphasis on handling kiln-dried lumber, but actually store it under conditions where moisture content may not be much lower than in air-dried material. In any event, kiln drying would seem to be a requisite to expanding sales in the metropolitan market (fig. 6).

With reference to price some dealers suggested that in order to enter the market, balsam fir would have to be from $5 to $15 per thousand board feet below western species.

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FIGURE 6. — Kiln drying is required to market lumber in the large metropolitan market.

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FIGURE 7. — Do-it-yourself customers often purchase lumber on appearance characteristics. Balsam fir studs with light color, straight grain, and small tight knots present an attractive appearance to the retail customer.

However, most thought a competitive price would be sufficient, provided quality, appearance, and availability were comparable to western species with similar characteristics, such as western white fir, western hemlock, western spruce, or lodgepole pine. Table 4 shows the price or price ranges various retail yards thought necessary to interest them in carrying local fir.

These survey figures indicate that there are two strong price ranges — $65 to $75 and $75 to $85 — and that the northern area is willing to pay a slightly higher price, on the average, than the more competitive metropolitan area.

Appearance, the third most important factor mentioned, was especially stressed in the metropolitan area. Balsam fir's light color, straight grain, and small sound knots are features which enhance salability. Many sellers in the Twin Cities said that balsam fir should have good acceptance by the expanded "do-it-yourself" or so-called "walk-in" trade. For this market, lumber is more often sold on looks than other characteristics (fig. 7). These buyers require that the lumber be well-machined, smooth, free of bark, with rounded corners (eased edges), trimmed to an exact length, and grade stamped. Other appearance features often influencing customers are end waxing or painting, and trade-name branding. Most of these features are considered highly desirable, if not essential, by retail yards in the metropolitan area.

TABLE 4. — *Purchase price ranges at which retail yards might be interested in handling balsam fir dimension lumber, 1964*
(Number of yards)

Price (dollars)	Twin Cities			Northern Minnesota		
	Grade not specified	Utility type	Standard type	Grade not specified	Utility type	Standard type
Less than $55	—	2	—	—	—	—
$55 - 65	—	3	—	1	—	—
$65 - 75	7	2	—	7	2	—
$75 - 85	6	—	1	7	—	—
More than $85	—	—	—	1	—	—

The fourth factor cited was reliability of supply. Once their customers have accepted the species, yards must be assured of a full-time, dependable supply and be able to obtain material consistently manufactured and graded whenever it is needed. This includes prompt delivery of orders within the time specified. Even though this was not mentioned as often, it is undoubtedly of great importance. Considering the proximity of the production area to the market, reliability of supply should be developed as a strong point for increasing the use of balsam fir.

These four factors — dryness, price, appearance, and availability — were by far the most commonly mentioned. Others cited were: (1) that a variety of lengths should be available in addition to studs, and (2) that stock should be palleted and packaged (wrapped) for easy handling and storage. A few dealers said they would be interested in handling balsam fir if it became accepted by the trade. Thus, one difficulty might be to find enough dealers in the metropolitan area to pioneer the use of local fir.

Even though few Twin Cities dealers were familiar with the physical and mechanical properties of balsam fir, the survey revealed a large majority interested in handling local fir. Thus it appears that there is a market potential. Most of the few who showed no interest were firms who sell only one mill's output (often their own) or do not wish to handle more than one species (usually Douglas-fir).

It should be understood that balsam fir is competing for the standard and better uses and it should not be thought of as only a "utility" grade product, both from a quality and price standpoint. It is widely used by contractors in the northern area for light frame construction.

Competitive Production Methods

To maintain a position in the market and to justify undertaking essential marketing techniques, any stud-mill installation would have to be of sufficient scale to assure the handling of repeat orders promptly with a standardized product. Because of the efficiency of western stud mills, a local producer would probably have to have a comparable installation to hold production costs to a minimum. This might be achieved by using a highly automated sawmill of special design, such as the very efficient scrag or twin-circle mills, now so common in the West and in Canada. In addition, a market for slabs, edgings, and other residue from the production processes may be needed; possible products are pulpmill chips, kiln or industrial fuel, and litter.

Recently a specialized stud mill sawing balsam fir has been established in northwestern Wisconsin (fig. 8). This mill produces studs on a twin-circle headrig; they are then kiln-dried, finished, end painted, graded, trademarked, and packaged. The finished product is marketed in midwestern metropolitan areas as "northern white fir." The average log size used by this mill is necessarily smaller than that used in the West. Specialty mills of this type in Canada sawing material similar in size to that found in the northern Lake States are producing 20 to 30 thousand board feet per shift.

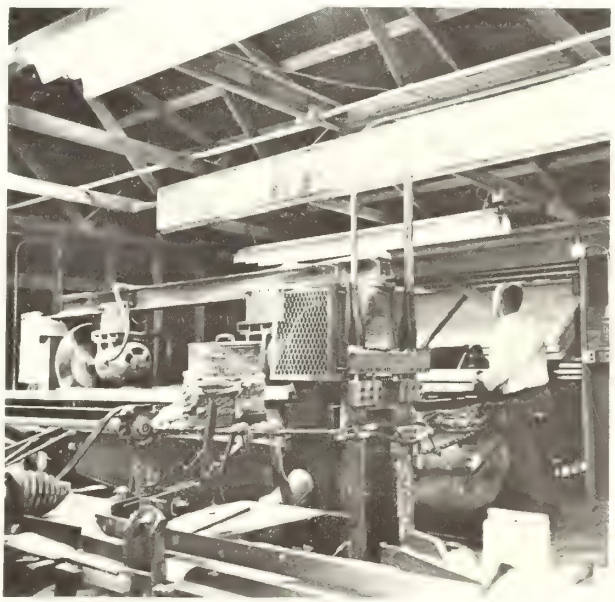

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FIGURE 8. — This mill, specializing in balsam fir studs, features a twin-circle scrag mill, kiln drying, and precision end-trimming. Residue from the production processes is chipped for pulpmill consumption.

Another possible production unit is one that makes cants for subsequent resawing by chipping the surfaces of the logs, thus producing chips instead of slabs. This reduces waste by eliminating much of the sawdust produced by conventional sawing methods.

One advantage that local producers have over western sources is the substantially lower freight rates to the Twin Cities and other midwestern markets such as Milwaukee and Chicago. Another is the possibility of serving these markets, particularly Minneapolis-St. Paul, with truckload lots. This could be important to some retail outlets because of the lower investment required to stock their yards. Certainly the quicker delivery times from local producers would be very desirable.

As discussed previously, the following techniques are thought to be necessary to make balsam fir studs widely acceptable in mid-western metropolitan markets: kiln drying, precision end-trimming (PET), eased-edge (EE), end waxing or painting, grade stamping, and branding with a trade name.

Grading and grade stamping are essential. Federal Housing Administration regulations require that lumber used under their jurisdiction must be grade stamped under rules of an accredited association, such as the Northern Hardwood and Pine Manufacturers Association, Green Bay, Wis., or the Western Wood Products Association, Portland, Ore. If the material is to compete in metropolitan markets compliance with FHA regulations would appear to be an absolute necessity.

SUMMARY AND CONCLUSIONS

In this survey of present and potential markets for balsam fir dimension lumber with 65 wholesale and retail Minnesota lumber yards in the sample, it was found that firms in the metropolitan Twin Cities area had had little experience in buying and selling local fir. In contrast, in northern Minnesota, a majority of the firms surveyed did handle such material. Of firms that sold balsam dimension lumber, satisfaction (as reflected by their customer purchases and "feed-back") was high.

Many retail firms (not now selling the material) expressed an interest in handling it. Of high importance was the price at which it could be procured. Price ranges varied, but $65 to $85 per MBF in the "Utility and Better" or "Standard and Better" grades were most frequently cited by retail firms as the purchase price range at which they might be interested. Probably because of discounts obtained due to large volume purchases of western species, the Twin Cities firms cited a slightly lower necessary supply price than did the northern small-town yards.

In addition to a delivered price competitive with western species, three other factors were most frequently cited as being important if markets for local fir are to be expanded. They were: (1) dryness, (2) appearance, and (3) reliable and continuous supply. Dryness was a more critical factor to Twin Cities firms than to northern firms where *well* seasoned, air-dried material seemed to be acceptable to many of the firms surveyed.

These findings suggest that there may be opportunities for increased marketing of balsam fir as 2x4 dimension lumber. There did not appear to be strong reservations against the suitability of the species for this product use, *if* price, manufacturing requirements (including kiln drying), and dependability of supply would be assured.

To meet these requirements, it would seem that producers must follow specialized and efficient manufacturing methods such as those used by western producers. Such facilities generally consist of highly mechanized sawmills of special design, such as scrag or

small twin-circle mills. In addition, kiln drying and prompt deliveries apparently would be requisites for successfully marketing the material produced.

Although efficient facilities are needed to keep product cost competitive, the scale of mill size and capital investment would have to be guided by the availability of raw material supplies in a particular area. One such specialized mill is now operating in northwestern Wisconsin (with log supplies obtained by truck from nearby northern Minnesota); and it is possible that several other northern Lake States locations may offer similar manufacturing opportunities.

Many phases of production, such as logging costs; cull percents; sawing, milling, and drying costs; amount of degrade; and ease of kiln drying, are not well known and need to be documented for Lake States conditions. Ignoring these for the moment, production of dimension lumber appears to offer an opportunity to put to practical and economic use our increasing volumes of small balsam fir sawtimber.

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